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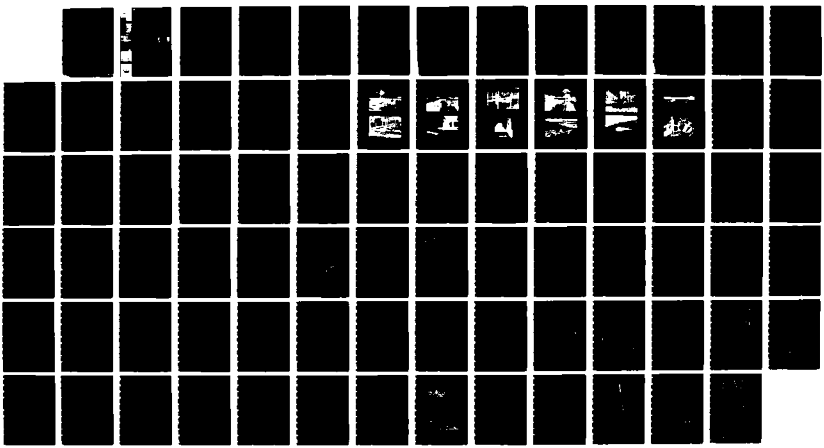

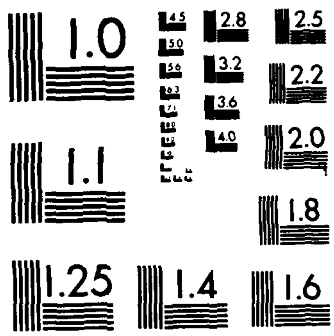
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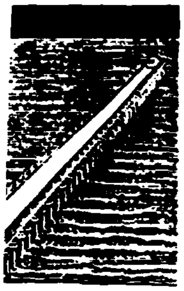

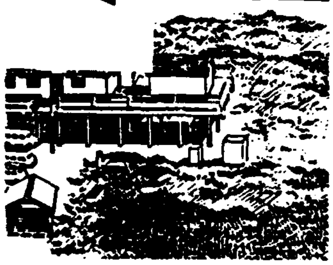

TECHNICAL REPORT CERC-87-10

# HURRICANE ELENA STORM SURGE DATA

## Report 3

by

Andrew W. Garcia, William S. Hegge

Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631



July 1987

Report 3 of a Series

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Under Hurricane Surge Prototype Data Collection
Work Unit 321-31662

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19 ABSTRACT (Continue on reverse if necessary and identify by block number)

A summary of storm surge high-water mark, hydrograph, and wave data acquired during and subsequent to Hurricane Elena is presented. The data were obtained and assembled as part of a long-term research effort by the US Army Corps of Engineers to establish a quantitative data set with the objective of providing in a series of documents the data necessary for simulation and verification of numerical surge models. The data contained herein were obtained primarily by the US Army Engineer Waterways Experiment Station and the US Army Engineer District, Mobile, of the US Army Corps of Engineers with supplemental data from contributing agencies and institutions. Additional information is included in the form of photographs and descriptive narrative to aid investigators in assessing the degree of importance of an individual measurement for the purpose of model verification.

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## PREFACE

The information and data presented herein were assembled and analyzed during 1985 to 1986 by authorization from the Office, Chief of Engineers (OCE), Coastal Engineering Area of Civil Works Research and Development, as a mission requirement of the Hurricane Surge Prototype Data Collection Work Unit 321-31662. Messrs. John H. Lockhart, Jr., and John G. Housley are the OCE technical monitors for the Coastal Engineering Research Area.

The work unit is a multiyear project of the US Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC), under general supervision of Dr. James R. Houston, Chief, CERC, Mr. Thomas W. Richardson, Chief, Engineering Development Division, and Dr. Dennis R. Smith, Chief, Prototype Measurement and Analysis Branch. Mr. Andrew W. Garcia is the Principal Investigator of the Hurricane Surge Prototype Data Collection work unit. Mr. William S. Hegge is the engineer in charge of data collection activities. This report was prepared by Messrs. Garcia and Hegge and edited by Ms. Shirley A. J. Hanshaw, Information Products Division, Information Technology Laboratory, WES.

A special acknowledgment is due Messrs. Geary McDonald and Harold Doyal of the US Army Engineer District, Mobile, for their cooperation in acquiring and assembling the high-water mark data and for providing interpretive guidance thereon.

This report is third in a series. Reports 1 and 2 provided similar data on Hurricanes Chris and Alicia, respectively.

Director of WES during the conduct of this study and preparation of this report was COL Allen F. Grum, USA. Commander and Director of WES during publication was COL Dwayne G. Lee, CE, and Technical Director was Dr. Robert W. Whalin.

CONTENTS

## CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

NON-SI units of measurement used in this report can be converted to SI (metric) units as follows:

| Multiply | By | To Obtain |
|---|---|---|
| feet | 0.3048 | metres |
| inches | 2.54 | centimetres |
| knots (international) | 0.5144444 | metres per second |
| miles (US statute) | 1.609347 | kilometres |
| millibars | 100.0000 | pascals |
| square miles (US statute) | 2.589998 | square kilometres |

# HURRICANE ELENA STORM SURGE DATA

## PART I: INTRODUCTION

1. This report is the third in a series* providing a data base directed toward verification of numerical storm surge models. As such, the emphasis is on quantitative measurements of the hydrodynamic and meteorologic parameters of Elena rather than documentation of structural damage or changes in coastal morphology. Photos 1-12 are intended to assist investigators in assessing the applicability of individual high-water marks in verifying a particular numerical model.

2. Contained herein are coastal and inland hydrographs, high-water contours, and basic meteorological data associated with Hurricane Elena. These data have been compiled from a variety of sources; consequently, they cannot be guaranteed to be absolutely accurate. Nevertheless, every reasonable effort has been made and great care taken to ensure the data are as consistent and complete as possible.

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* Thomas H. Flor. 1983 (Jul). "Poststorm Reconnaissance of Tropical Storm Chris," Miscellaneous Paper HL-83-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.
Andrew W. Garcia and Thomas H. Flor. 1984 (Nov). "Hurricane Alicia Storm Surge and Wave Data," Technical Report CERC-84-6, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

## PART II: METEOROLOGICAL DISCUSSION

3. Elena was first identified on satellite imagery as a well-organized cloud pattern near the Cape Verde Islands on 23 August 1985*. The system moved rapidly across the tropical Atlantic with no significant development until 28 August when it deepened to a tropical depression while located just to the east of Cuba. As it moved over Cuba, it strengthened rapidly to a tropical storm and was named Elena. Movement across the island of Cuba did not appear to significantly affect intensification, as the central pressure of Elena decreased by 9 mb** during this time. After moving into the Gulf of Mexico on 29 August, Elena quickly strengthened to a hurricane and appeared to be headed toward the Alabama/Mississippi coastline.

4. At about noon Greenwich mean time (Gmt) on 30 August, Elena began to turn toward the east and during the next 36 hr moved toward the west coast of Florida before becoming almost stationary at 0000 Gmt 31 August near latitude 29 deg north and longitude 84 deg west. During the next 24 hr, there was little translational movement of the hurricane, but intensification continued so that by early morning of 1 September the central pressure had dropped from 977 to 965 mb. At this time, Elena began to move slowly back toward the west on a track roughly paralleling the coastline of the Florida panhandle. Elena continued to intensify as it moved westward and at 0000 Gmt 2 September reached its greatest intensity with maximum sustained winds of approximately 126 mph and a central pressure of 951 mb. Between midnight and noon Gmt 2 September, there was an increase in Elena's forward speed which was accompanied by a slight decrease in intensity. Elena made landfall in the vicinity of Biloxi, Miss., at approximately 1330 Gmt 2 September. Maximum sustained winds at landfall were approximately 115 mph, and the central pressure was 959 mb. Elena quickly lost strength as it moved inland and was downgraded to a tropical depression by the morning of 3 September. Figure 1 shows the approximate track of Elena. Table 1 contains the preliminary best track information.

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* This meteorological discussion and information contained in Table 1 are taken from the "Preliminary Report on Hurricane Elena" provided by The National Hurricane Center.

** A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page 3.

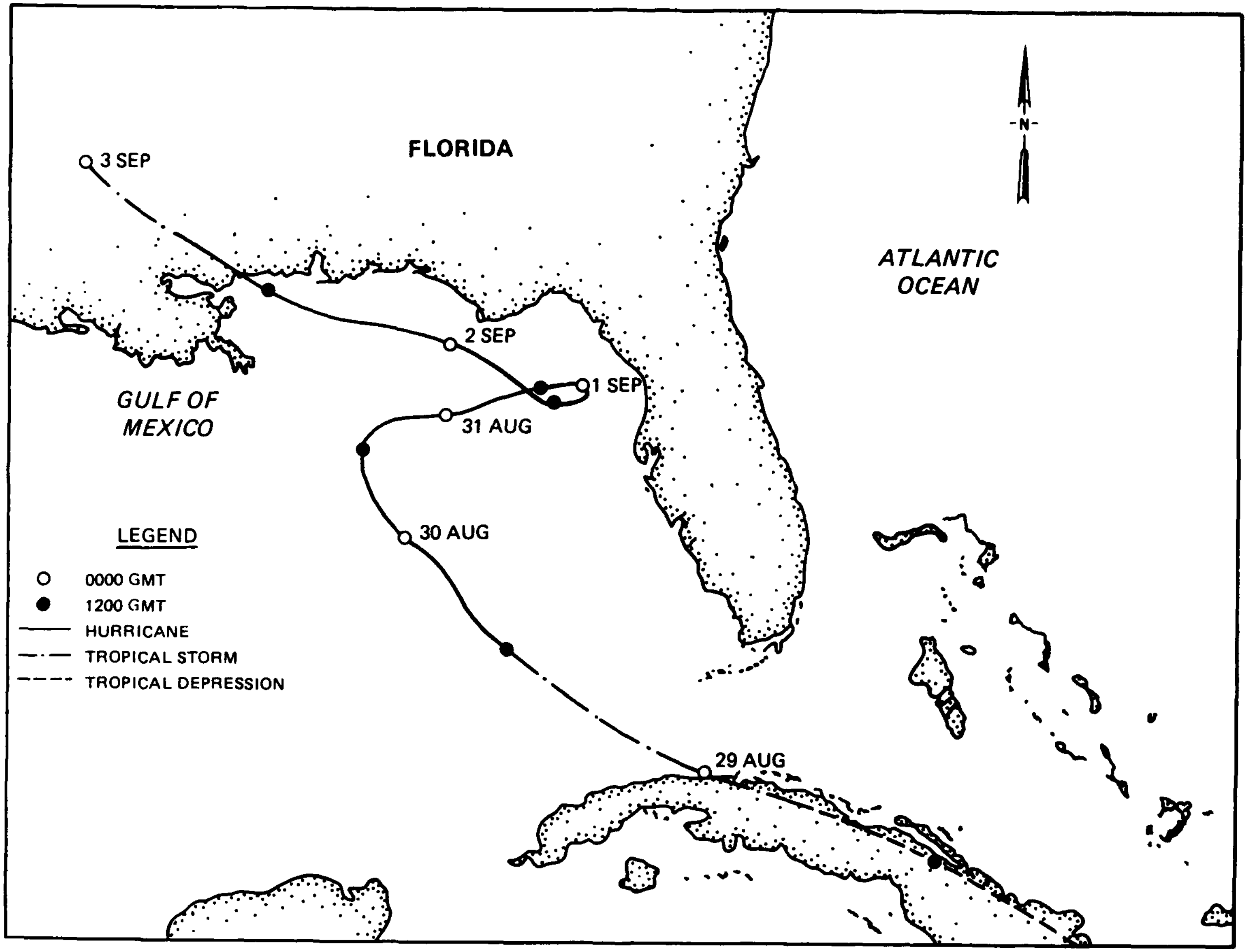



Figure 1. Approximate track of Hurricane Elena

**Table 1**

**Preliminary Best Track, Hurricane Elena**

**28 August-4 September 1985**

| Date | Time Gmt | Position, deg Latitude | Position, deg Longitude | Pressure mb | Wind knots | Stage |
|---|---|---|---|---|---|---|
| 8/28 | 0000 | 19.8 | 74.0 | 1,012 | 30 | Tropical depression |
| | 0600 | 20.8 | 76.0 | 1,010 | 30 | Tropical depression |
| | 1200 | 21.8 | 78.0 | 1,008 | 30 | Tropical depression |
| | 1800 | 22.6 | 80.0 | 1,006 | 45 | Tropical storm |
| 8/29 | 0000 | 23.2 | 81.8 | 1,004 | 50 | Tropical storm |
| | 0600 | 24.0 | 83.5 | 1,000 | 55 | Tropical storm |
| | 1200 | 25.0 | 85.0 | 994 | 65 | Hurricane |
| | 1800 | 25.9 | 85.8 | 990 | 70 | |
| 8/30 | 0000 | 26.6 | 86.6 | 986 | 75 | |
| | 0600 | 27.3 | 87.2 | 980 | 80 | |
| | 1200 | 27.9 | 87.3 | 974 | 90 | |
| | 1800 | 28.3 | 86.8 | 978 | 90 | |
| 8/31 | 0000 | 28.4 | 86.0 | 977 | 90 | |
| | 0600 | 28.6 | 85.3 | 976 | 90 | |
| | 1200 | 28.8 | 84.4 | 975 | 90 | |
| | 1800 | 28.8 | 84.0 | 974 | 90 | |
| 9/01 | 0000 | 28.8 | 83.8 | 971 | 95 | |
| | 0600 | 28.6 | 83.9 | 965 | 100 | |
| | 1200 | 28.6 | 84.2 | 961 | 105 | |
| | 1800 | 28.9 | 84.8 | 954 | 110 | |
| 9/02 | 0000 | 29.4 | 85.9 | 953 | 110 | |
| | 0600 | 29.7 | 87.3 | 957 | 105 | |
| | 1200 | 30.2 | 88.8 | 959 | 100 | |
| | 1800 | 31.0 | 90.4 | 990 | 60 | Tropical storm |
| 9/03 | 0000 | 31.9 | 91.8 | 1,000 | 45 | Tropical storm |
| | 0600 | 32.4 | 92.8 | 1,004 | 30 | Tropical depression |
| | 1200 | 33.2 | 93.7 | 1,006 | 25 | |
| | 1800 | 34.5 | 94.0 | 1,008 | 25 | |
| 9/04 | 0000 | 35.9 | 93.9 | 1,010 | 20 | |
| | 0600 | 37.0 | 93.2 | 1,010 | 20 | |
| | 1200 | 38.0 | 92.5 | 1,010 | 20 | |
| | 1800 | 38.8 | 91.4 | 1,010 | 20 | |
| Landfall at: | | | | | | |
| 9/02 | 1300 | 30.4 | 89.2 | 959 | | Hurricane |

## PART III: FIELD ACTIVITIES

5. The development of Elena had been tracked by the staff of the Coastal Engineering Research Center (CERC), and by the morning of 28 August 1985, a decision was reached to dispatch the hurricane field team to the vicinity of the Mississippi/Alabama coastline. On the morning of 29 August, the CERC field team began to deploy the onshore gages and by that evening had instrumented 10 sites from Slidell, La., to Pascagoula, Miss. At this time, Elena was about 350 miles southeast of New Orleans, La., moving toward the northwest at about 20 mph. During the night of 29/30 August, Elena became stationary near 28.0 deg north latitude, 86.5 deg west longitude. The best available guidance at this time indicated a turn toward the northeast and, accordingly, the field team proceeded to the vicinity of Ft. Walton Beach, Fla.

6. At about noon on 30 August, Elena began to move toward the northeast with indications of landfall near Panama City, Fla. On this basis, the field team deployed the remaining instruments in the Panama City vicinity. Meanwhile, during the late afternoon and evening of 30 August, Elena continued to turn toward the east and headed in the direction of Cedar Key, Fla. The hurricane continued on this easterly track until the morning of 31 August when it again became stationary near 29 deg north latitude, 84 deg west longitude. Having exhausted its supply of instruments, the CERC field team retrieved the instruments which had been deployed along the Mississippi/Alabama coast to use in the event Elena turned toward the north and threatened the Florida panhandle.

7. By the afternoon of 1 September, Elena had assumed a westward track paralleling the west Florida coastline. Because the track of the hurricane was nearly parallel to the coast, a relatively small change in direction would result in a significant change in landfall position. The CERC field team was instructed to deploy the remaining instruments as long as possible from Ft. Walton Beach, Fla., westward. The field team worked its way to the west until late evening of 1 September when directed by civil authorities to leave the area. Elena continued to move westward through the night of 1 September, finally making landfall near Biloxi, Miss., early the morning of 2 September.

8. Following the passage of Elena, the CERC field team returned to the area of landfall to conduct a poststorm survey of high-water levels. The findings of the poststorm survey are discussed in Section V.

## PART IV: HYDROGRAPHIC DATA

9. The effects of hurricane Elena upon coastal waters in the Gulf of Mexico were somewhat unusual in that clear evidence of a departure from expected water levels was apparent as early as 28 August when the center of the hurricane was over Cuba (see Plate 5). Abnormally high water levels gulfwide often accompany hurricanes in the Gulf of Mexico; this effect is traditionally termed the "hurricane induced surge forerunner." However, evidence of a forerunner usually does not occur until the center of the storm passes through the Yucatan or Florida Straits.

10. Figures 2 and 3 show the locations of hydrographs contained herein which cover the reach of coastline from Gulfport, Miss., to Carabelle, Fla. The hydrographs were obtained from the area of coastline primarily affected by Elena during the 48 hr prior to landfall and are shown in Plates 1 through 17. Because Elena meandered through the eastern gulf from 29 August until 2 September, many of the hydrographs show multiple peaks associated with the storm, particularly along the coast of the Florida panhandle. Table 2 contains a listing of the maximum surge elevations recorded while Elena was in the Gulf of Mexico.

11. Inspection of the hydrographs may show a higher water level occurring on 30 August 1985 than on the day of landfall, 2 September 1985. All the hydrographs with maximum water levels occurring on 30 August are the result of the effects of the storm being superimposed on a high astronomical tide. This is clearly evident in Plate 5 which also shows the predicted tide during this period of time. The maximum surge values contained in Table 2 reflect this fact. Plates 4 and 5 are the hydrographs obtained on the bayward and seaward sides of Dauphin Island, respectively. These hydrographs are particularly noteworthy, as it was this location that experienced the highest winds recorded on land during the hurricane.

12. The hydrograph obtained at Gulfport, Miss. (Plate 1), shows a pronounced drawdown of nearly 6 ft followed by a rapid increase in water level coinciding with passage of the hurricane. The hydrograph obtained at Pascagoula, Miss. (Plate 3), shows a similar sequence except the drawdown is only about 1.5 ft. In contrast, both hydrographs obtained at Dauphin Island, Ala. (Plates 4 and 5), show a rapid increase in water level of about 4.2 ft followed by drawdowns of about 0.8 ft at the gage on the seaward side of

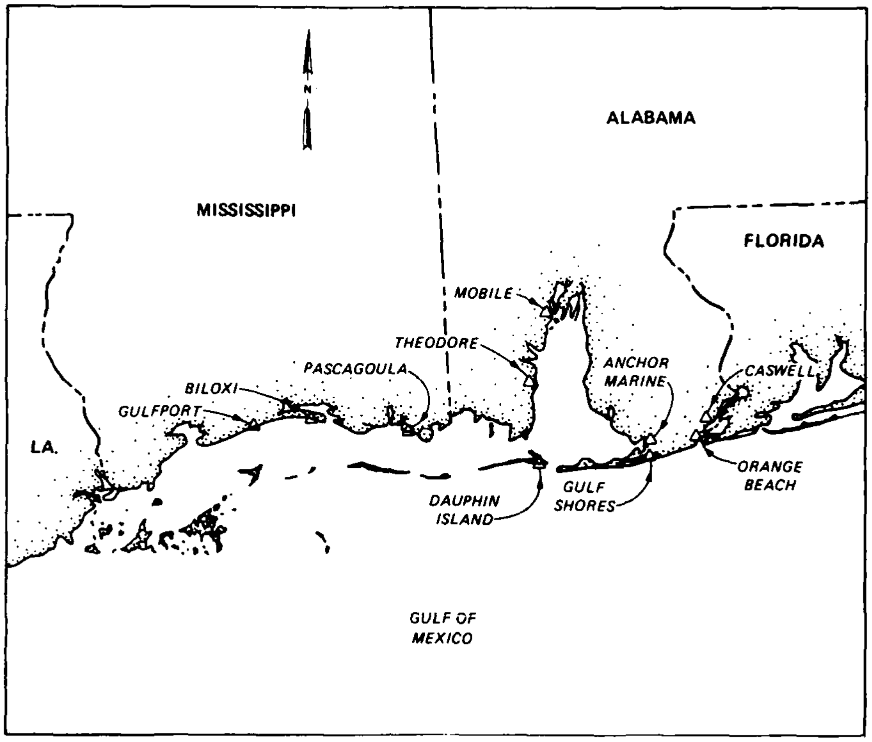



Figure 2. Locations where hydrographs were obtained (Plates 1 through 11)

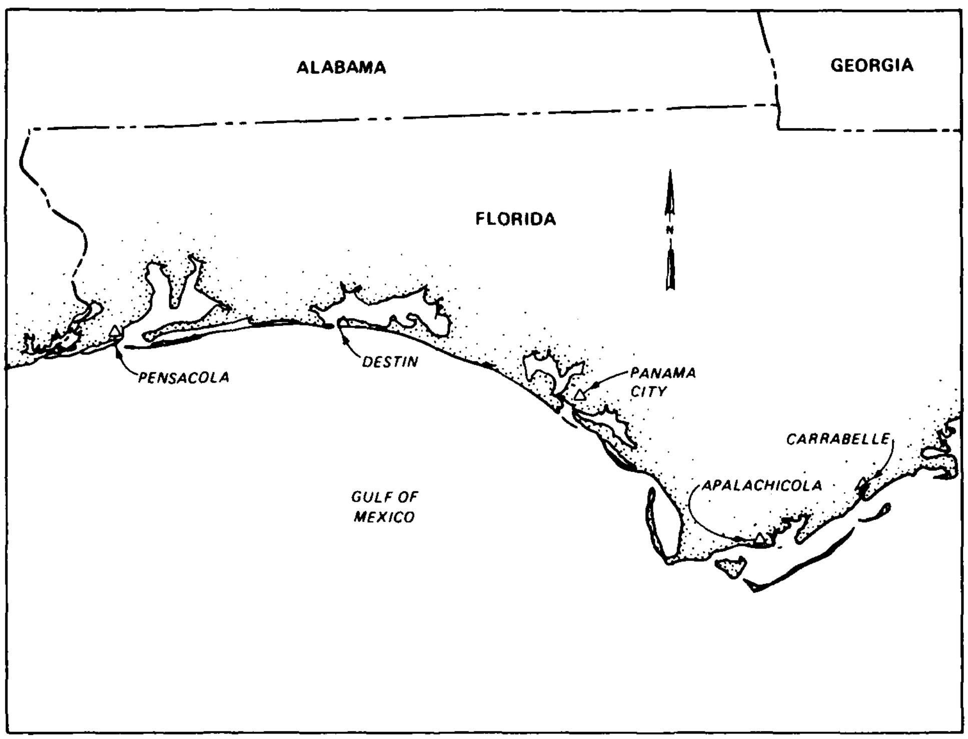



Figure 3. Locations where hydrographs were obtained (Plates 12 through 17)

Table 2

Hydrograph Information

| Location | Maximum Water Elevation, ft | Date/Time | Datum | Source |
|---|---|---|---|---|
| Gulfport, Miss. | 5.4 | 09/02/0900 | NGVD | CE |
| Biloxi, Miss. | 6.0 | 09/02/0800 | NGVD | CE |
| Pascagoula, Miss. | 5.5 | 09/02/0600 | NGVD | CE |
| Dauphin Island, Ala.(1) | 4.2 | 09/02/0320 | NGVD | CE |
| Dauphin Island Ala.(2) | 4.3 | 09/02/0325 | MSL | NOS |
| Theodore, Ala. | 3.8 | 09/02/1200 | NGVD | CE |
| Mobile, Ala.* | 3.8 | 09/02/1220 | NGVD | CE |
| Anchor Marine, Ala.*,** | 3.0 | 08/29/1400 | NGVD | CE |
| Gulf Shores, Ala. | 2.9 | 09/02/1330 | NGVD | CE |
| Orange Beach, Ala. | 4.0 | 09/02/0200 | NGVD | CE |
| Caswell, Ala. | 2.6 | 09/02/1200 | NGVD | CE |
| Pensacola, Fla. | 2.9 | 09/02/0400 | NGVD | CE |
| Destin, Fla.(1) | 1.9 | 09/02/1600 | NGVD | CE |
| Destin, Fla.(2)*,** | 2.9 | 08/30/1800 | NGVD | CE |
| Panama City, Fla.*,** | 3.5 | 08/30/1100 | NGVD | CE |
| Apalachicola, Fla. | 4.6 | 09/01/2000 | NGVD | CE |
| Carabelle, Fla. | 7.1 | 09/01/1630 | NGVD | CE |

Note: NOS = National Ocean Service
CE = Corps of Engineers
NGVD = National Geodetic Vertical Datum
MSL = mean sea level
* Incomplete record.
** Gage failed prior to landfall.

Dauphin Island (2) and about 2.5 ft at the gage on the landward side of Dauphin Island (1). However, neither the Theodore, Ala. (Plate 6), nor the Mobile, Ala. (Plate 7), gages which are located in Mobile Bay exhibit the sharp rise seen in both Dauphin Island gages. Since the sharp water level rise just prior to landfall does not occur in records immediately to the east or west of Dauphin Island, it is a feature unique to the offshore location of the island.

## PART V: POSTSTORM INSPECTION

13. A poststorm survey of high-water marks resulting from Hurricane Elena was made during the period of 6-8 September 1985. The survey included the reach of coastline from Bay St. Louis, Miss., to Panama City, Fla. The westernmost extent of the surge-induced flooding appeared to be in the vicinity of Clermont Harbor, Miss., southwest of Bay St. Louis. The level of the high-water marks did not exceed +5 ft NGVD.

14. Trash lines remained all around the shores of Biloxi Bay. On the eastern side of the bay at the location of the Biloxi fishing bridge (the remnant of the old Highway 90 bridge), the surge washed across part of a shorefront road. Photo 1 shows this trash line being surveyed. The elevation of the surge induced flooding did not exceed +3 ft NGVD at this point.

15. Between Biloxi Bay and Pascagoula Bay, 15 miles to the east, the elevation of the high-water mark was about +6 ft NGVD. At the location of the Mississippi Gulf Coast Research Lab on Davis Bayou (southeast of Ocean Springs, Miss.), the high water overtopped the docks and bulkheads around a small-boat harbor (Photo 2). A large amount of debris was left at the +5-ft NGVD line, but there was minimal flooding at the laboratory facilities.

16. The hardest hit area on the coast was Dauphin Island, Ala., which was directly in the path of the hurricane's track just prior to landfall. There was extensive wind damage all over the island, but the majority of the damage caused by the surge was seen on the western half of the island where the surge passed completely over the island at a number of locations. This resulted in gullying which damaged roads (Photo 3) and undermined the foundations of houses (Photo 4). The high-water mark at these locations measured +6.5 ft NGVD. The small-boat harbor on the northeast side of the island suffered very little structural damage, but some of the boats were damaged or sunk when they broke free of their moorings (Photo 5). The only major surge-induced damage on the eastern end of the island occurred at Pelican Point where the deck of the wooden pier supporting the NOS/CE surge gage was destroyed (Photo 6). The high-water level at this location was about +6.7 ft NGVD with wave runup heights exceeding +8.0 ft NGVD.

17. The amount of surge related damage within Mobile Bay was minimal, with most locations showing a measured high-water elevation of +4 ft NGVD or less. Surge levels on the large spit protecting the eastern side of the

entrance to Mobile Bay exceeded +8 ft NGVD and reached the base of the seawall in Fort Morgan State Park (Photo 7). Within the boundaries of the state park, there were several locations where the surge passed completely over the spit, resulting in highway erosion (Photo 8). While surge related damage was confined to the highway, high winds totally destroyed one building and severely damaged several others in the park. Surge elevations dropped rapidly east of the park to an average of +4 ft NGVD. This was sufficient to cause some flooding in the communities located between the park and the city of Gulf Shores. However, the amount of structural damage was minimal as can be seen by the house shown in Photo 9.

18. Throughout the western part of the Florida panhandle the measured high-water marks were less than +5 ft NGVD. Thus, actual damage resulting from surge was limited to minor highway damage and to structures located very close to the high-water mark such as the chain link fence in Pensacola Beach shown in Photo 10. In Destin, the surge and wave runup cut through a dune line (Photo 11) and flooded a lagoon located behind the dune line. The water level in the lagoon rose approximately 5 ft but did not flood any of the structures surrounding it. Farther east along the coast, surge levels continued to diminish with most high-water marks at an elevation of less than +4 ft NGVD. However, some damage did occur at several locations. One such location was the Dan Russell City Pier in Panama City Beach, Fla. The concrete decking on the end of the pier was lifted and broken by waves (Photo 12). This damage occurred at an elevation of approximately +20 ft NGVD, at a location where the measured wave runup did not exceed +10 ft NGVD, and is probably the result of the seaward end of the pier being in the breaker zone during part of the storm.

19. A series of contour maps showing the high-water marks from Biloxi, Miss., to Pensacola, Fla., is presented in Appendix A.

## PART VI: CONCLUSION

20. Elena reached Category 3 status on the Simpson-Saffir Scale of Hurricane Intensity which ranges from a minimum of 1 to a maximum of 5. However, during the 3 days prior to landfall, most of the northern and, at times, some of the eastern portions of the hurricane were overland. Consequently, by the time Elena made landfall near Gulfport, Miss., where gusts of 121 mph were recorded, gusts of only 51 mph were reported at Slidell, La., just 38 miles to the west. This occurrence indicates that hurricane force winds were probably confined to a relatively small area near the eye of the storm which helps explain the relatively low surge values recorded in Mobile Bay. Comparison with 1979 hurricane Frederic, also a Category 3, shows a value of 8.0 ft MSL was recorded at the Mobile gage location, greater than twice the value recorded during Elena. Moreover, the maximum gusts for both hurricanes were recorded at Dauphin Island, Ala., 142 mph during Frederic and 136 mph during Elena, a difference of only 6 mph. Other factors which probably contributed to the lower surge values in Mobile Bay were differences in track and forward speed between Elena and Frederic. The track of Frederic was more northerly and just to the west of Mobile Bay at the time it moved inland as compared with Elena. The forward speed of Elena was significantly greater than that of Frederic during the 12 hr just prior to landfall.

21. Heavy rainfall resulting from Elena occurred in central to northern Florida along a stretch from Tampa to Tallahassee, Fla. This reach of coastline coincides with the area affected by the hurricane while it was nearly stationary during the period 31 August to 2 September 1985. Conversely, exceptionally heavy rainfall was not reported about the time of landfall although heavy rainfall did occur in Arkansas after the hurricane went inland. It is reasonable to conclude, therefore, that coastal flooding which occurred in the area of landfall was primarily because of surge effects.

Photo 1. Surveying debris line at the east end of old Highway 90 fishing bridge, Biloxi, Miss.

Photo 2. Debris line on docks at the Mississippi Gulf Coast Research Lab on Davis Bayou

Photo 3. Damage to road on north side of Dauphin Island, looking west

Photo 4. Foundation damage on the western half of Dauphin Island, bay side

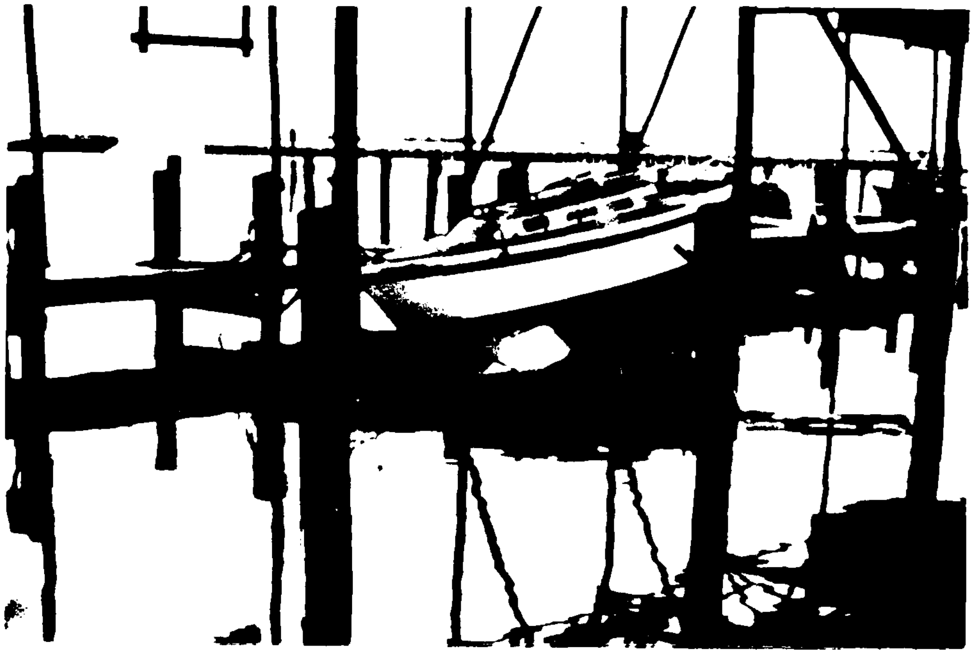


Photo 5. Boat damage on the northeast side of Dauphin Island

Photo 6. Pier damage at Pelican Point on the eastern end of Dauphin Island showing the NOS tide station where hydrograph of Dauphin Island (2) was obtained

Photo 7. Debris line at the foot of the seawall, Ft. Morgan State Park, Ala., looking west

Photo 8. Evidence of overwash resulting in road damage in Ft. Morgan State Park, looking north

Photo 9. Debris line on house steps near Gulf Shores, Ala.

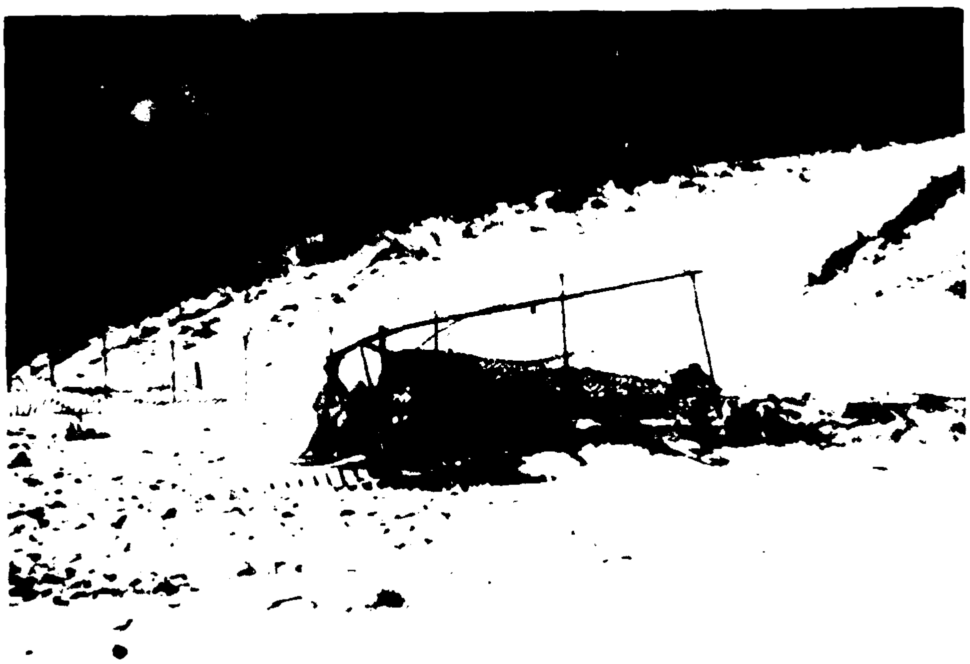


Photo 10. Damage to chain link fence in front of dune line at at Pensacola Beach, Fla.

Photo 11. Cut through dune line in Destin, Fla., looking south

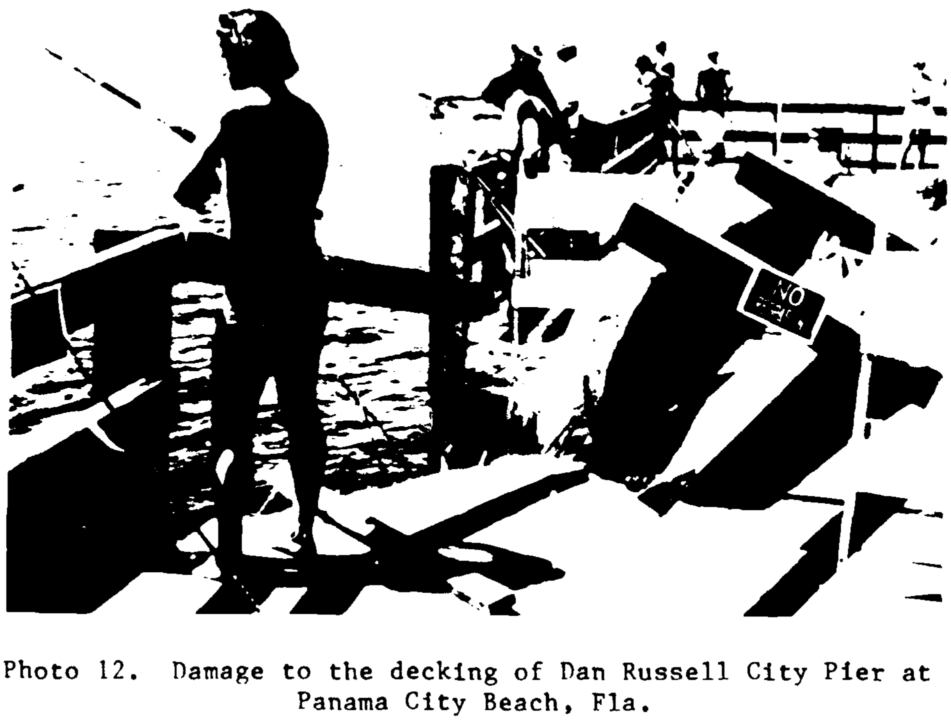
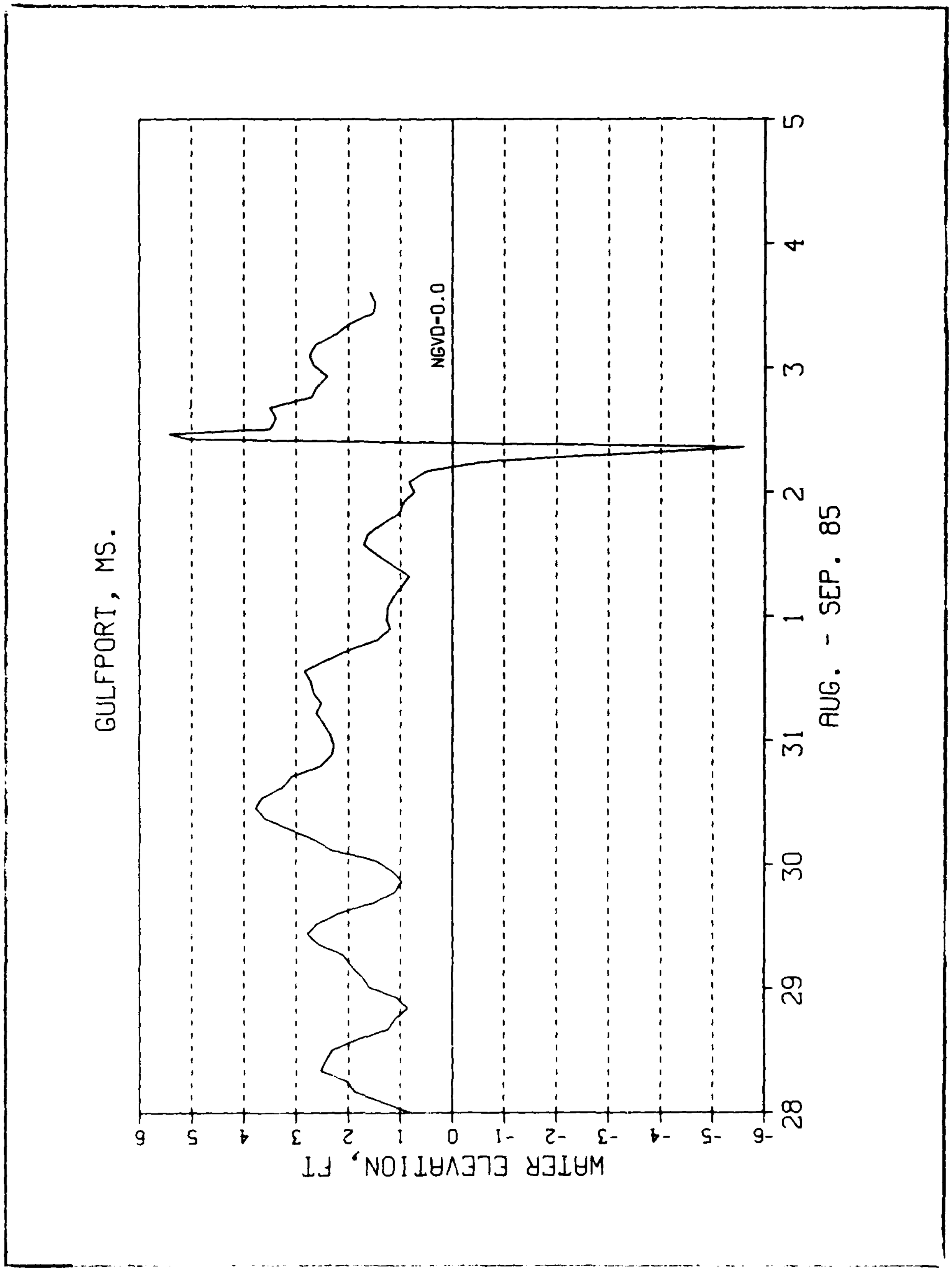



Photo 12. Damage to the decking of Dan Russell City Pier at Panama City Beach, Fla.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-6

PLATE 1

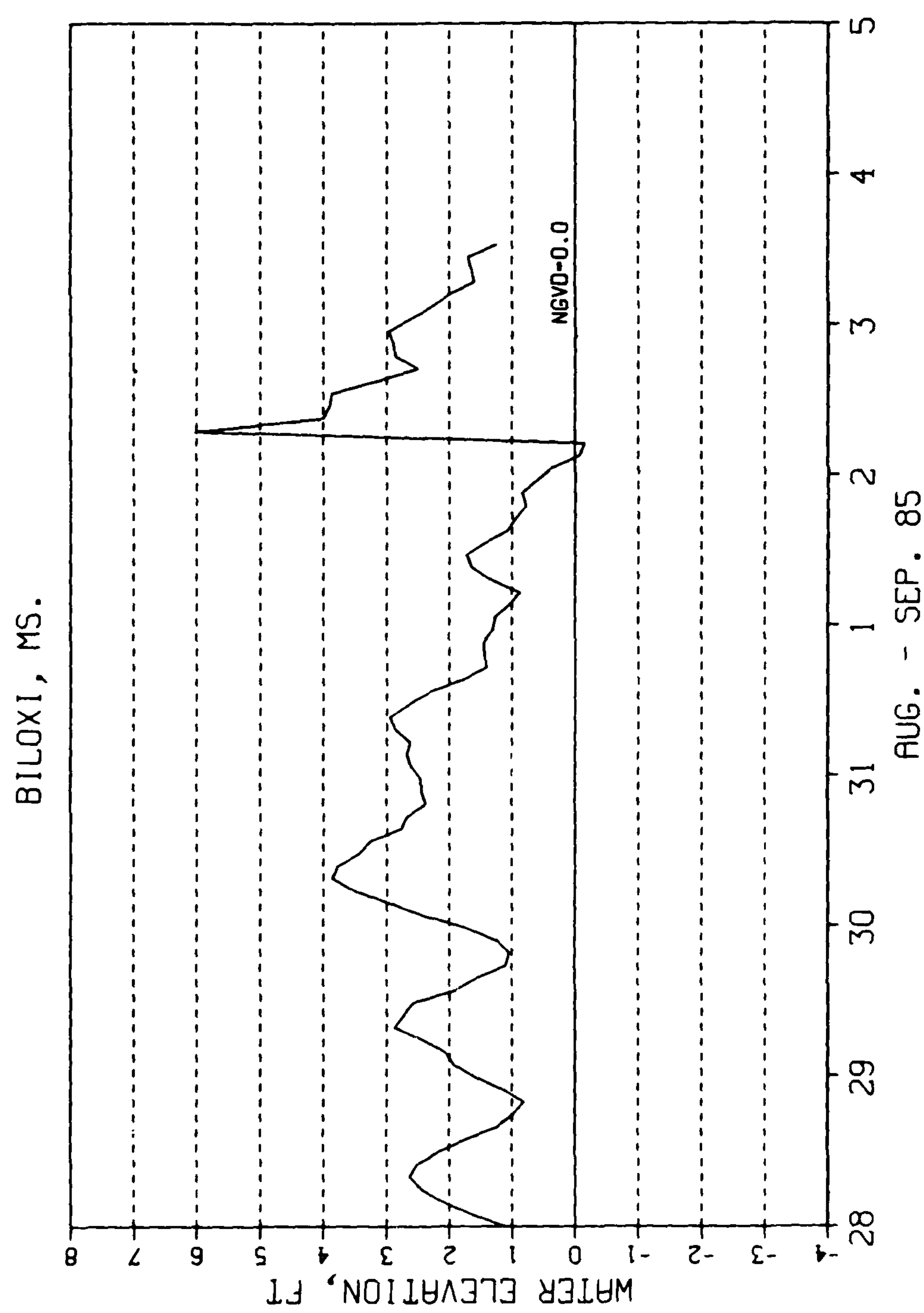
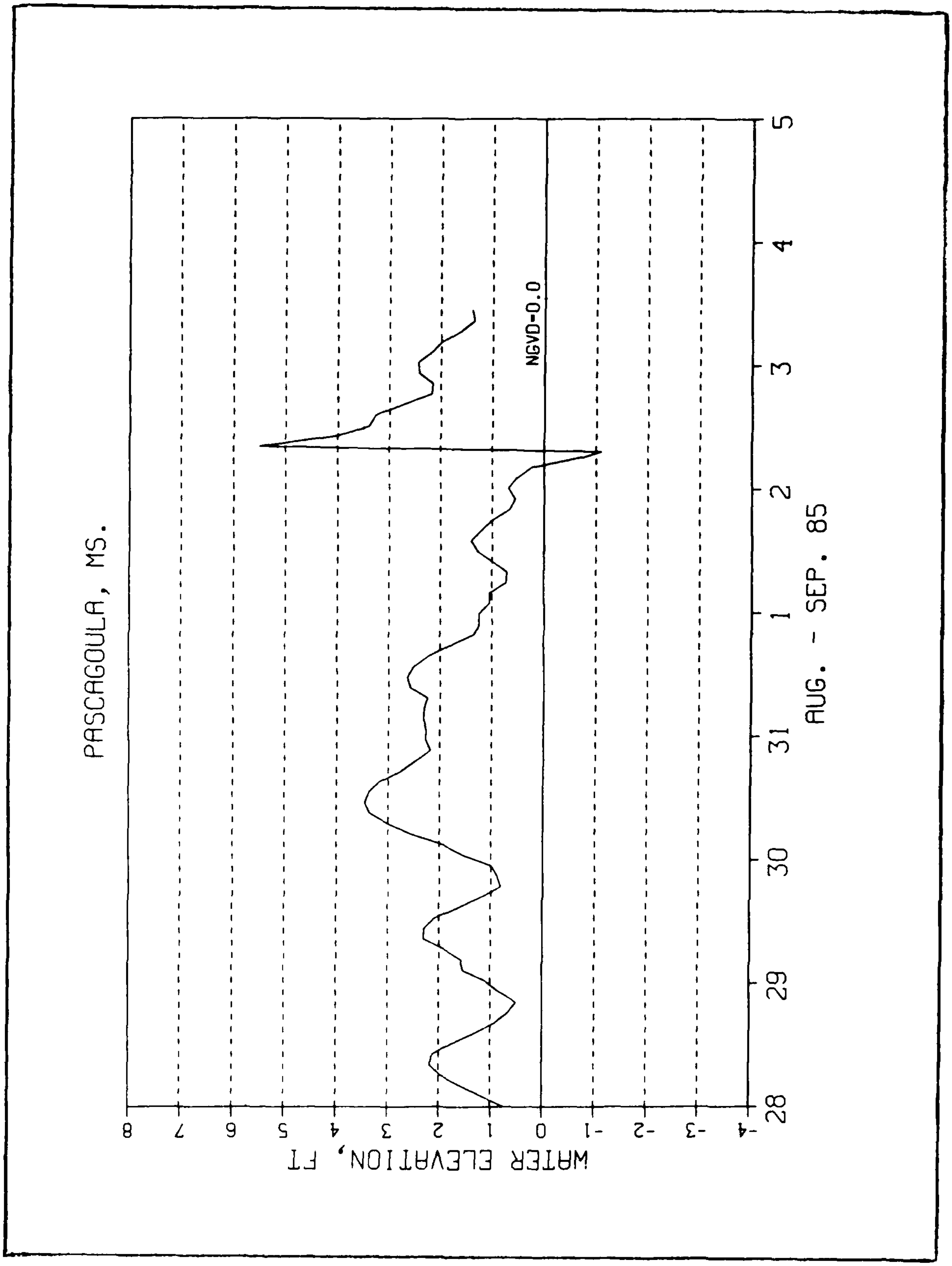

BILOXI, MS.
NGVD-0.0
AUG. - SEP. 85
WATER ELEVATION, FT
28
29
30
31
1
2
3
4
5
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4

PLATE 2


PASCAGOULA, MS.
WATER ELEVATION, FT
AUG. - SEP. 85
NGVD-0.0
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5

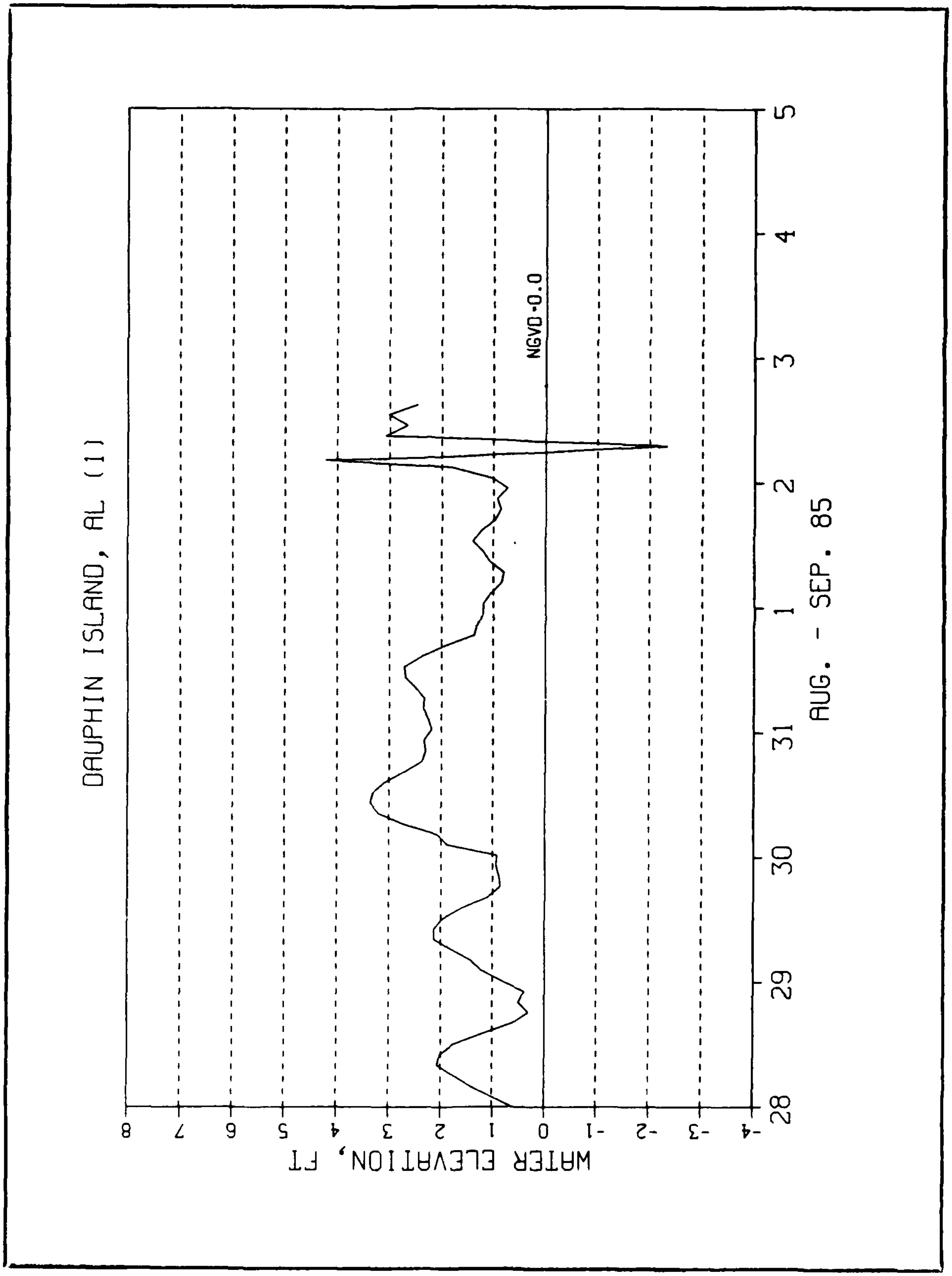
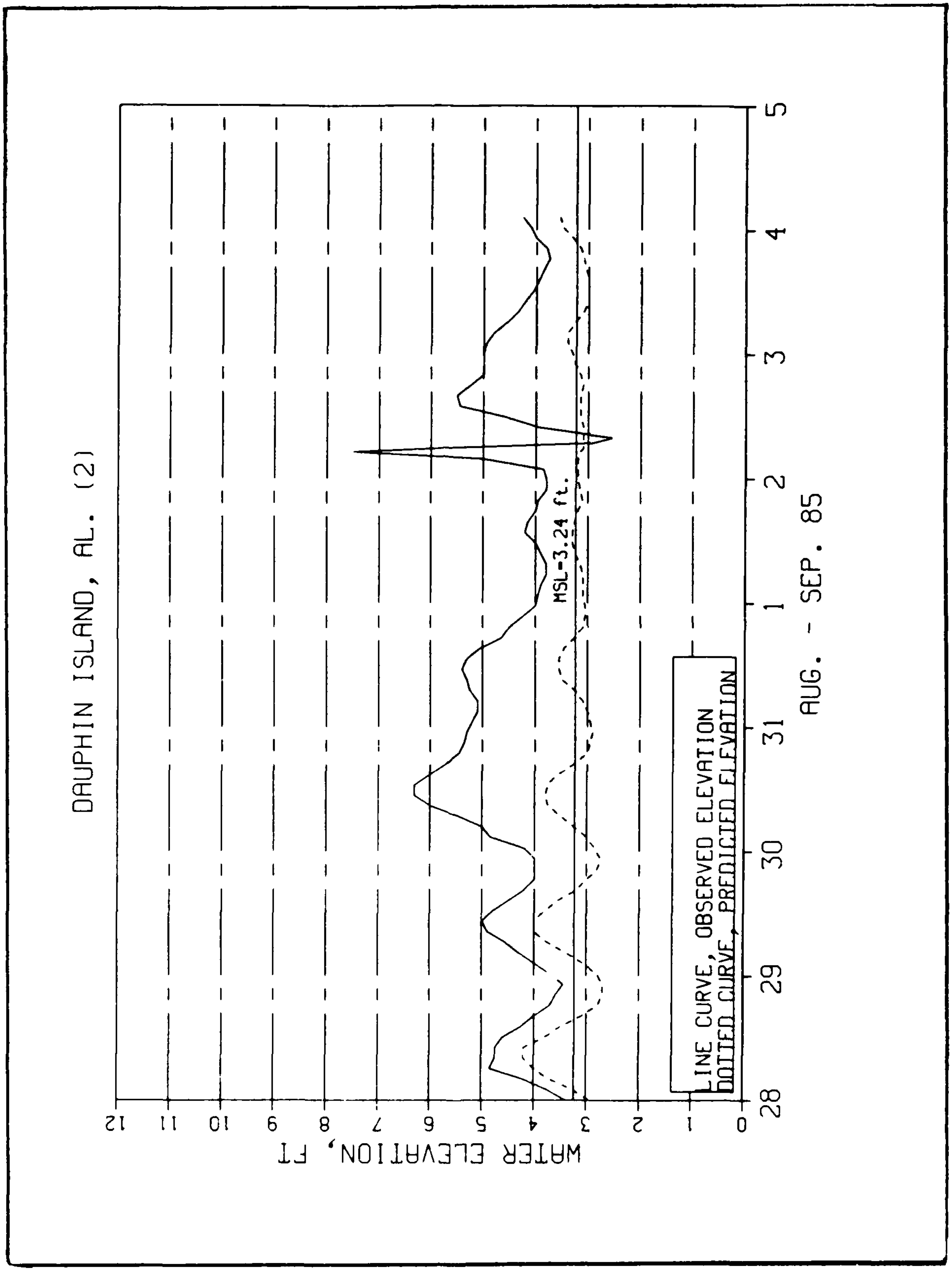

DAUPHIN ISLAND, AL (1)
WATER ELEVATION, FT
-4 -3 -2 -1 0 1 2 3 4 5 6 7 8
NGVD-0.0
28 29 30 31 1 2 3 4 5
AUG. - SEP. 85

PLATE 4



DAUPHIN ISLAND, AL. (2)
WATER ELEVATION, FT
0
1
2
3
4
5
6
7
8
9
10
11
12
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85
MSL-3.24 ft.
LINE CURVE, OBSERVED ELEVATION
DOTTED CURVE, PREDICTED ELEVATION

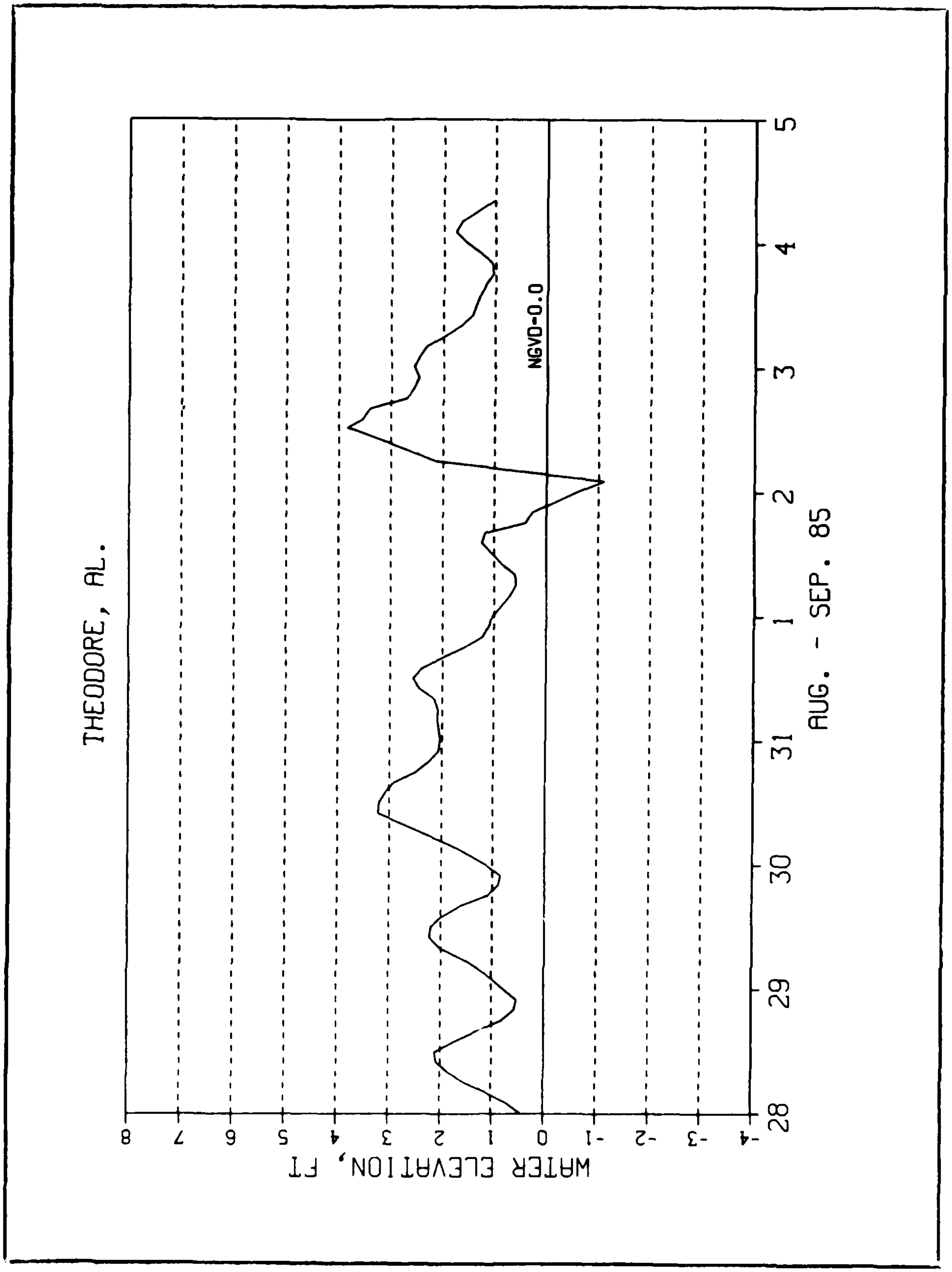
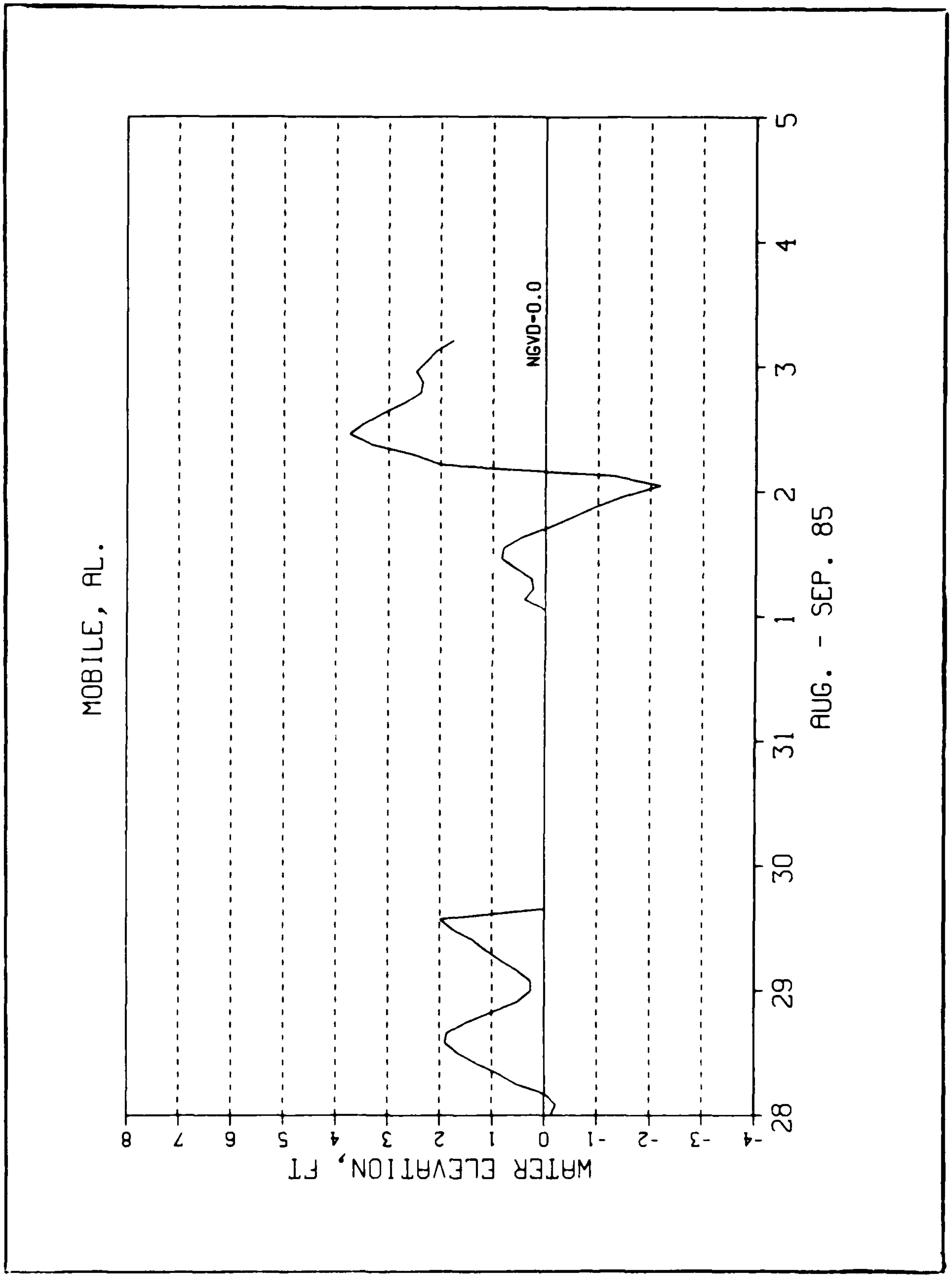
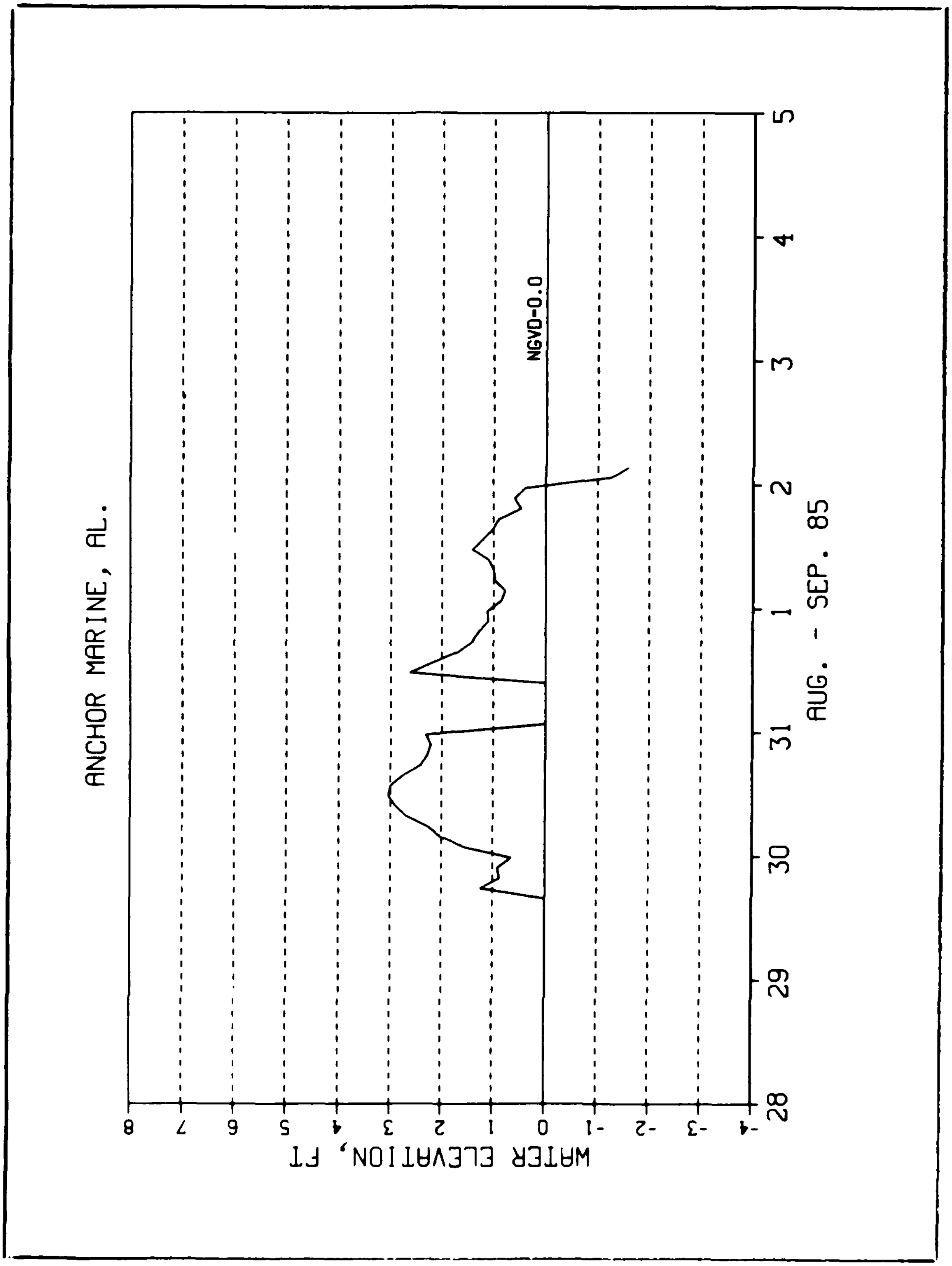

THEODORE, AL.
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85

PLATE 6

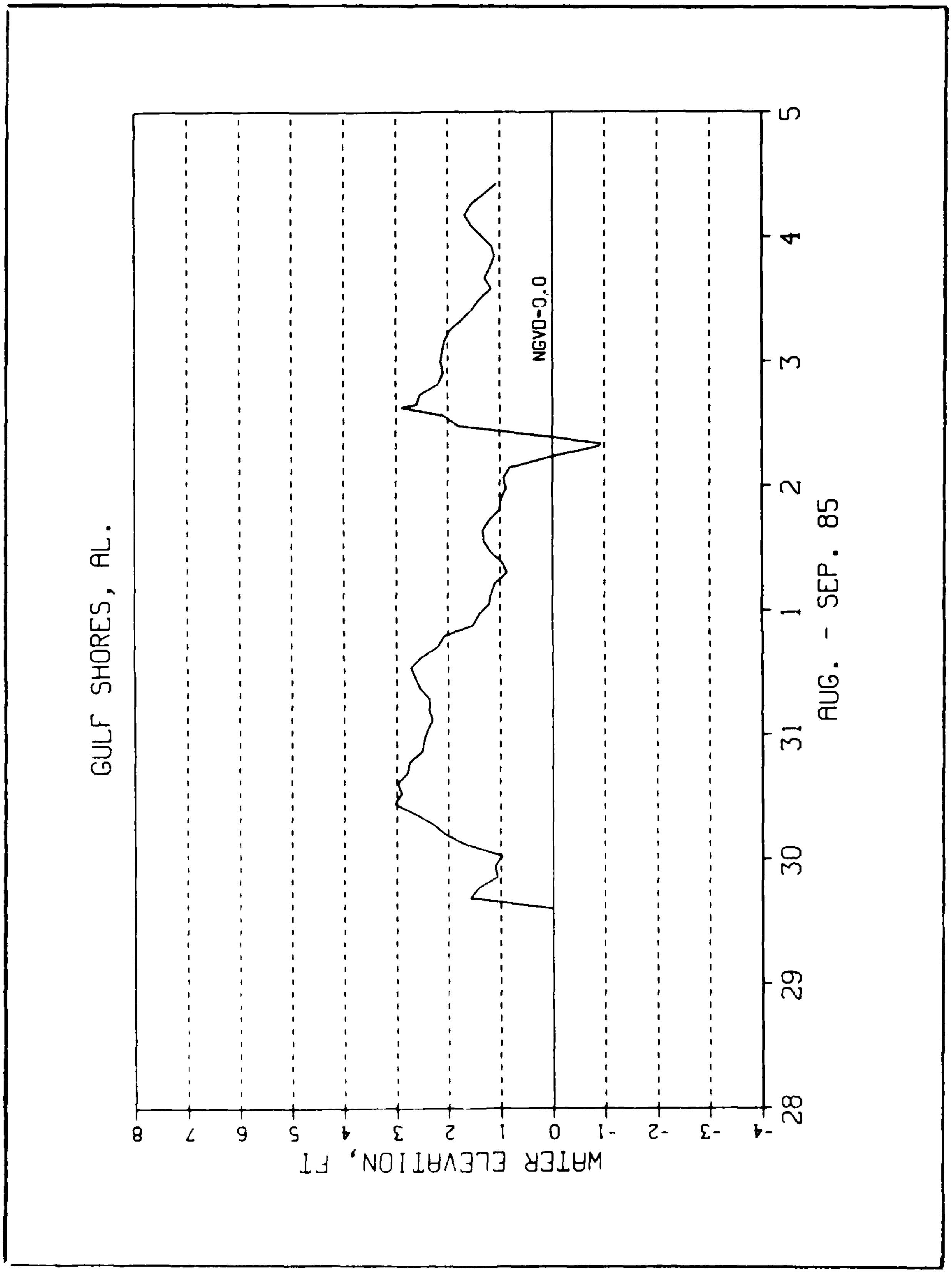


MOBILE, AL.
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
NGVD-0.0
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85



ANCHOR MARINE, AL.
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85


PLATE 8


GULF SHORES, AL.
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85

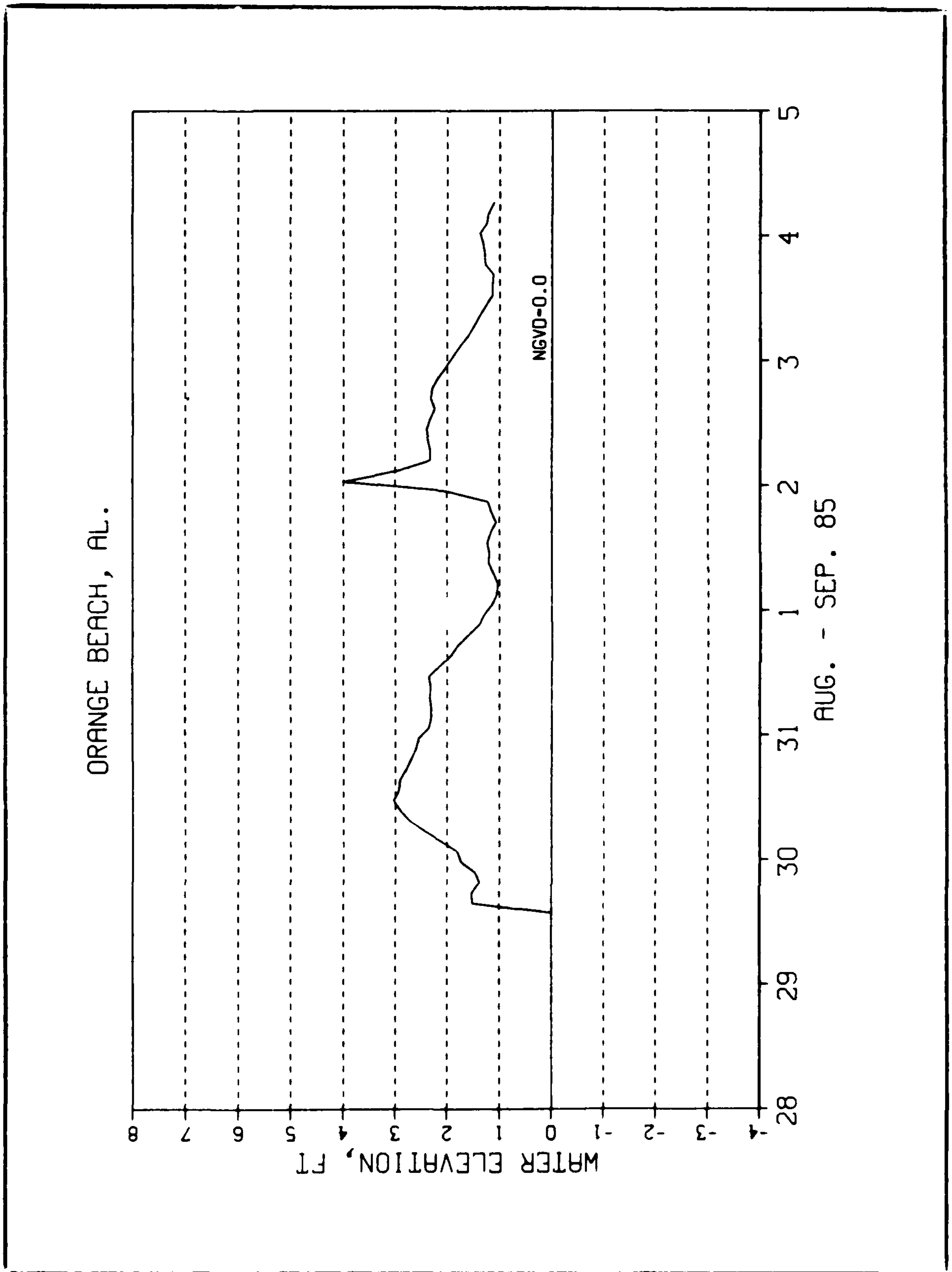
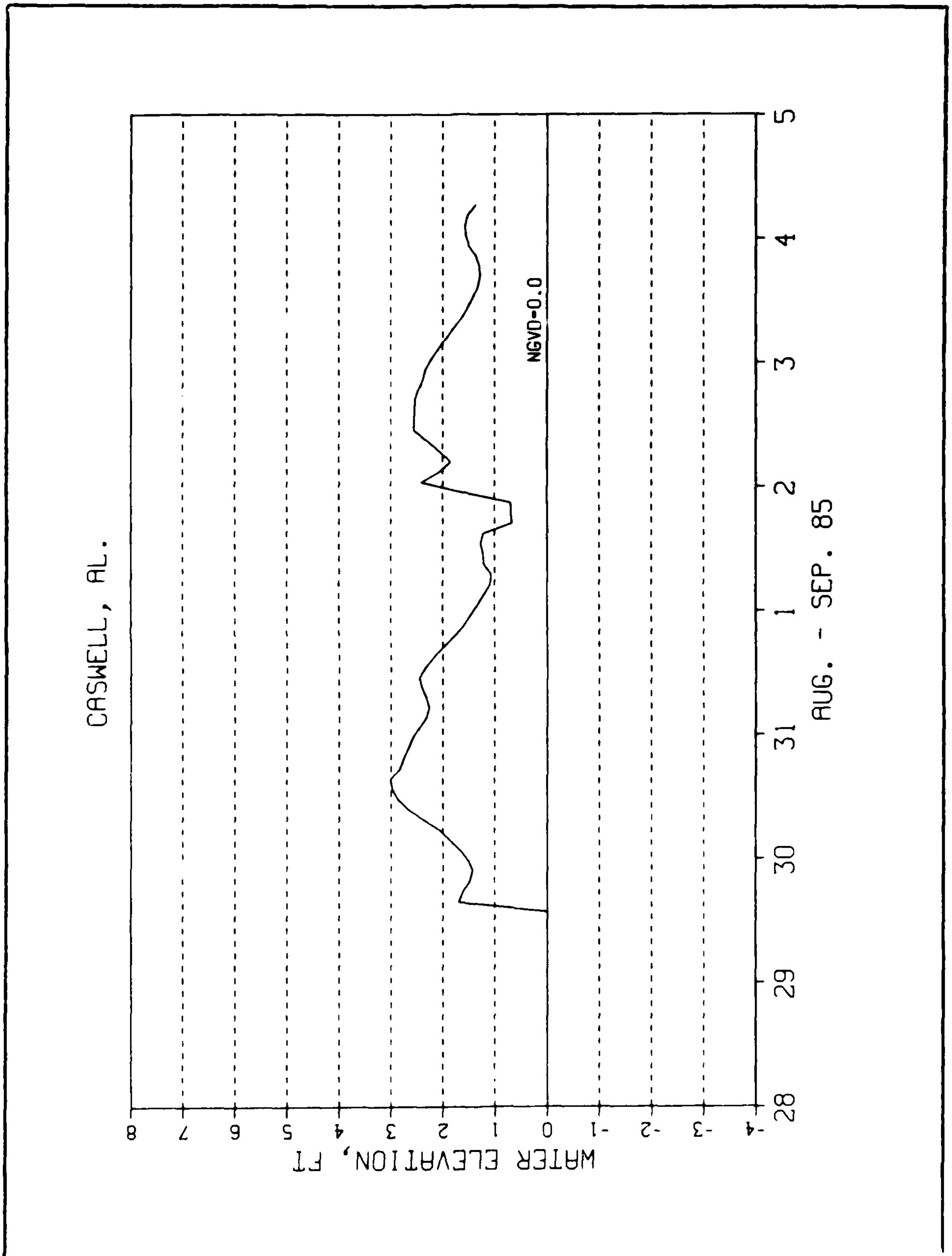

ORANGE BEACH, AL.
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85

PLATE 10



CASWELL, AL.
NGVD=0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85

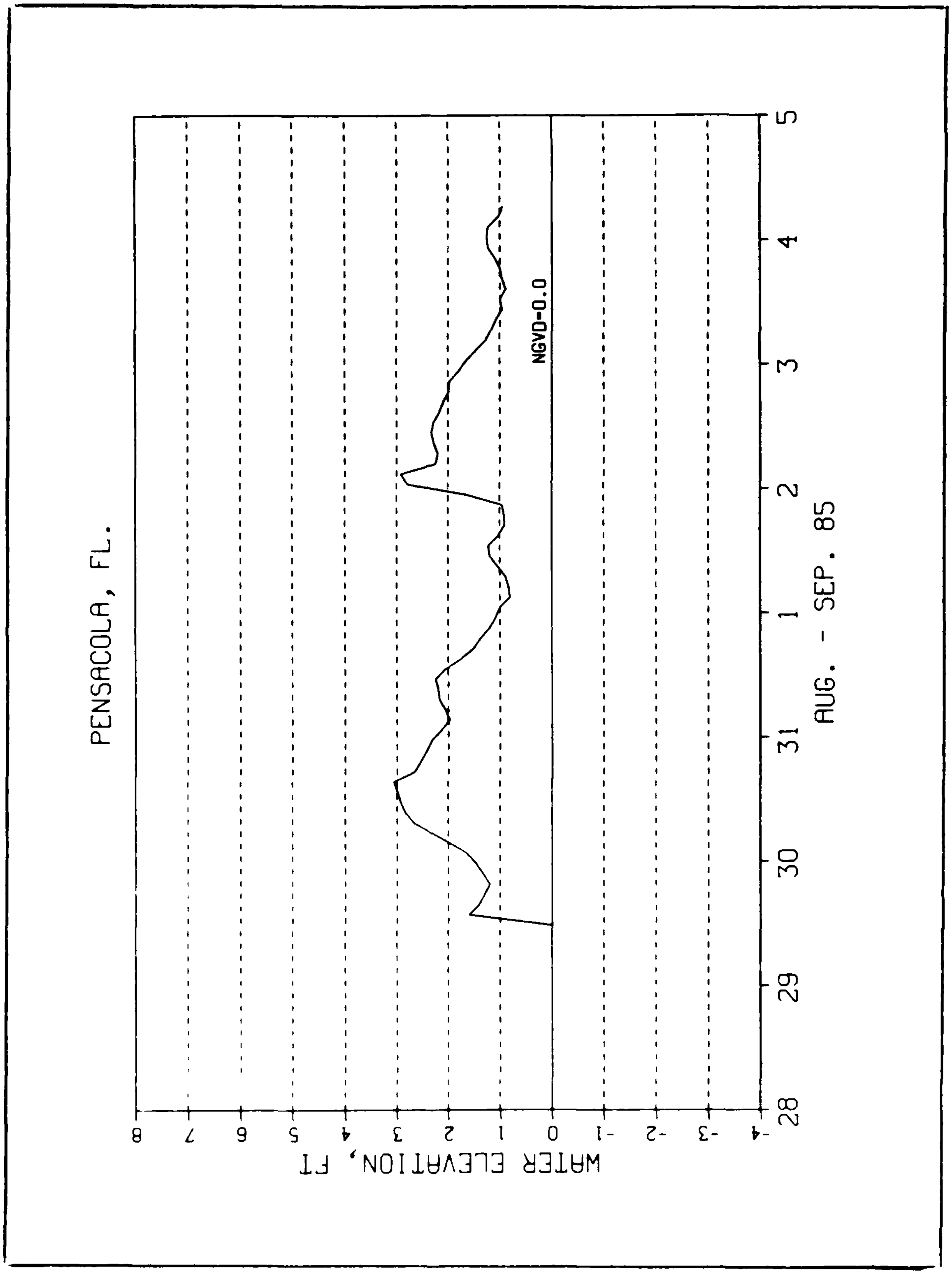
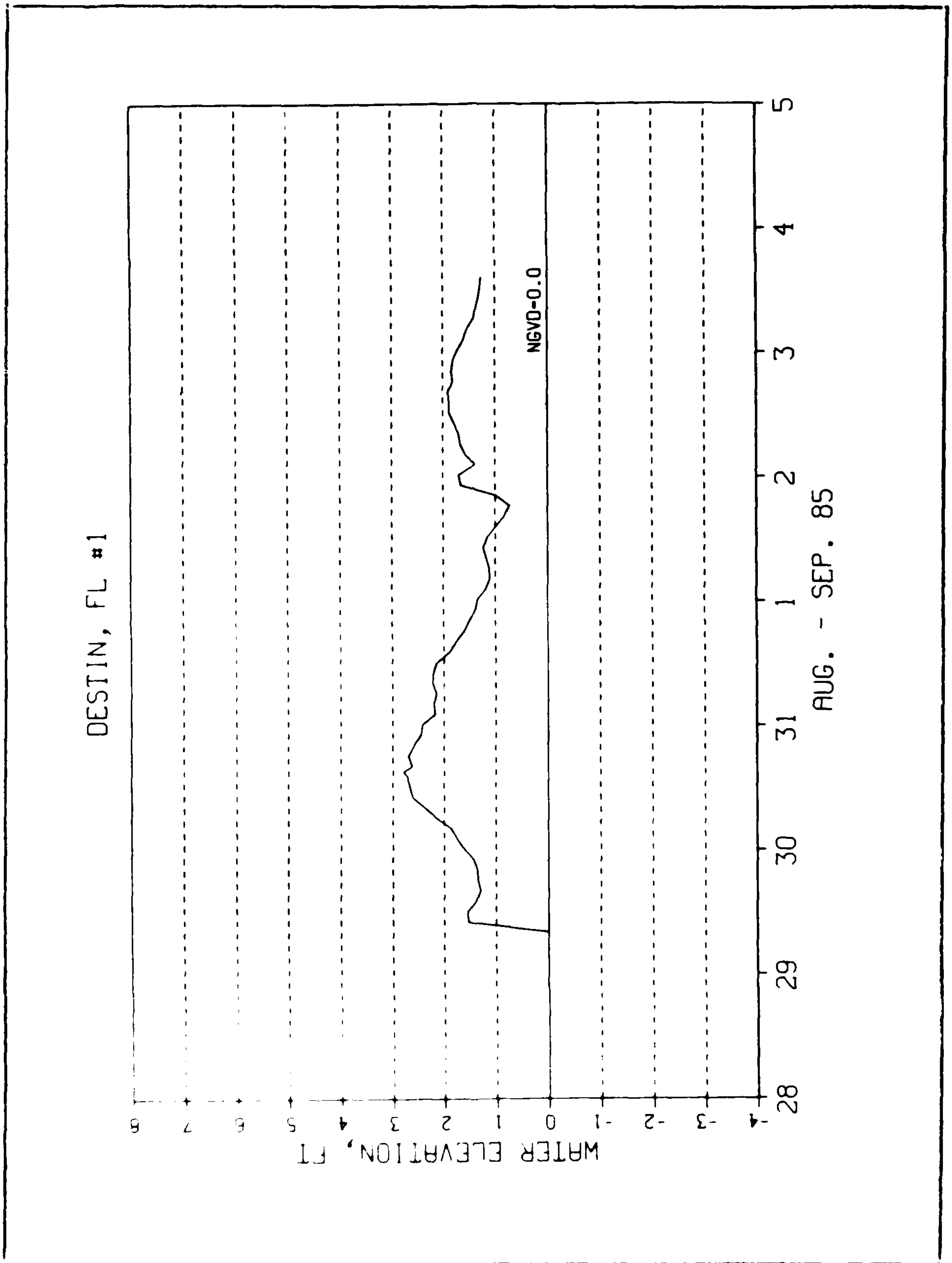

PENSACOLA, FL.
AUG. - SEP. 85
WATER ELEVATION, FT
NGVD-0.0
28
29
30
31
1
2
3
4
5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8

PLATE 12



DESTIN, FL #1
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85

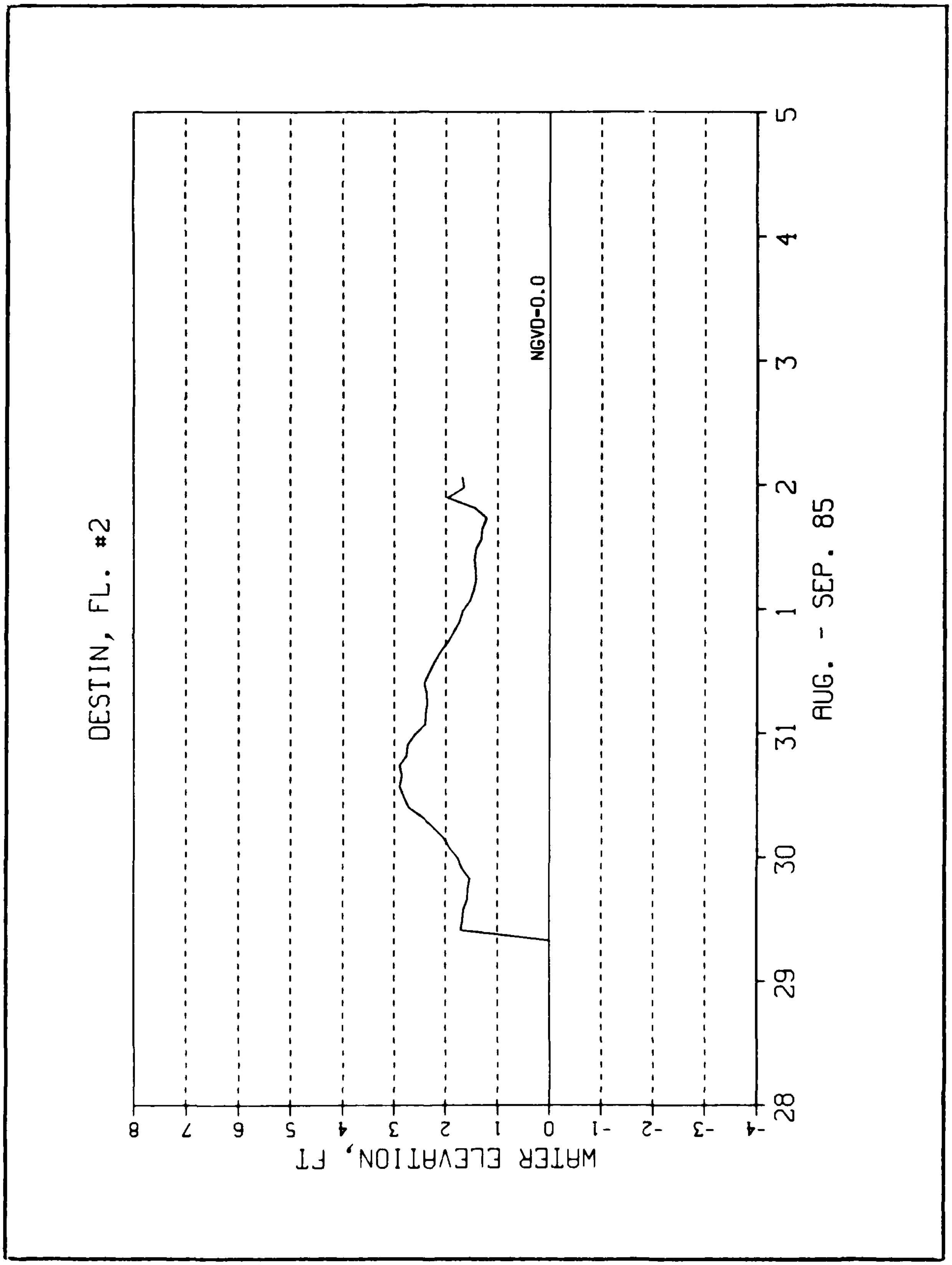
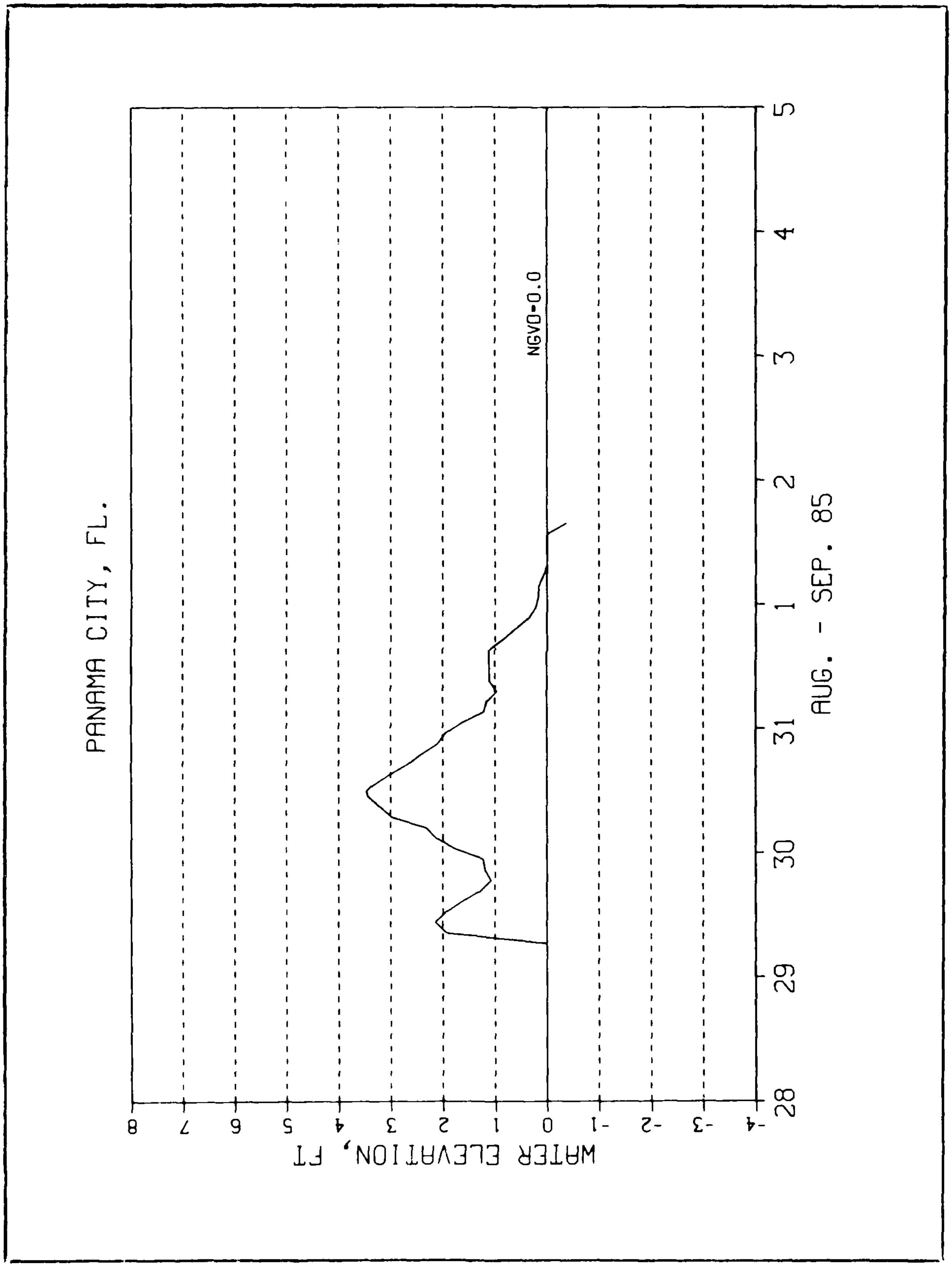
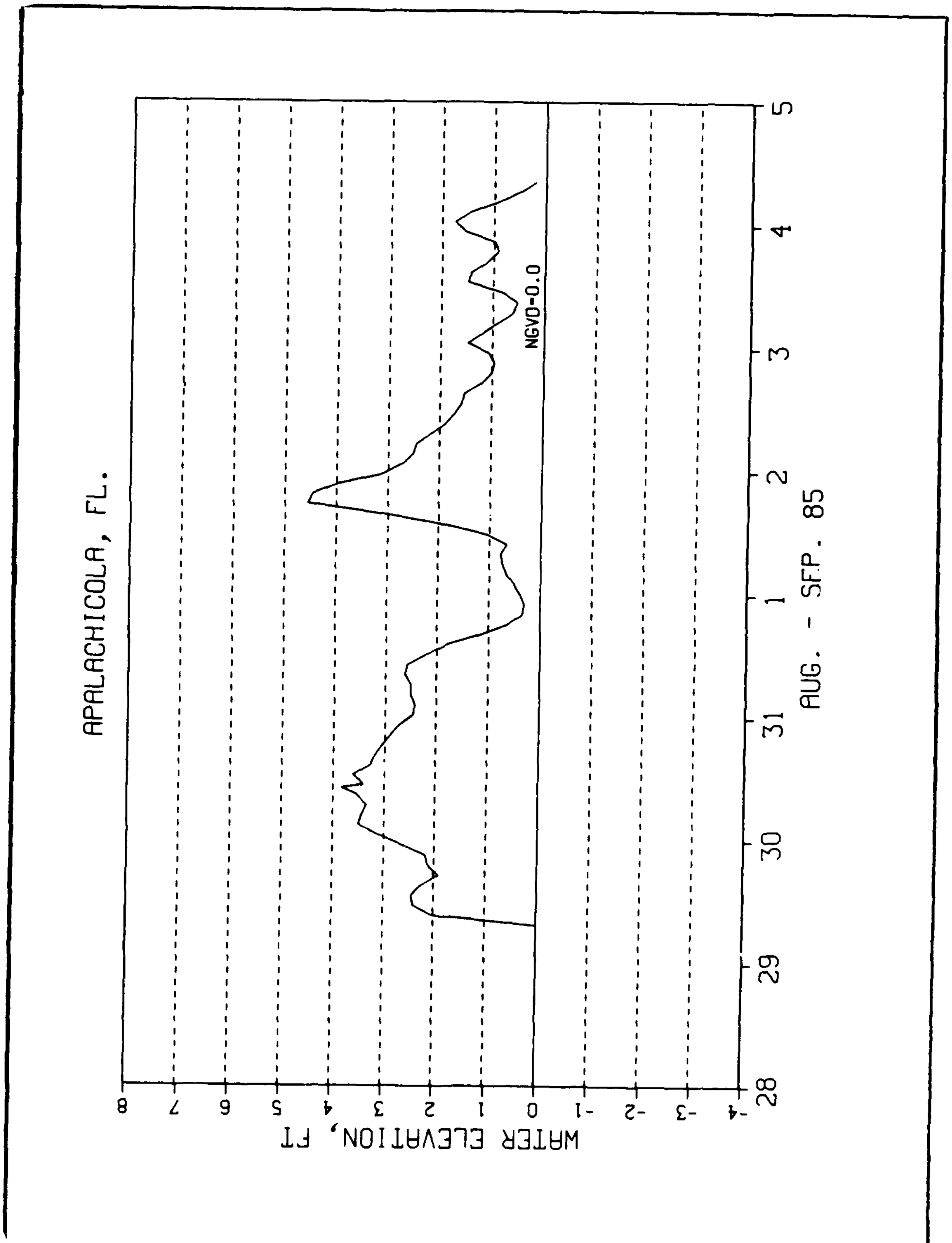

DESTIN, FL. #2
NGVD-0.0
WATER ELEVATION, FT
AUG. - SEP. 85
-4 -3 -2 -1 0 1 2 3 4 5 6 7 8
28 29 30 31 1 2 3 4 5

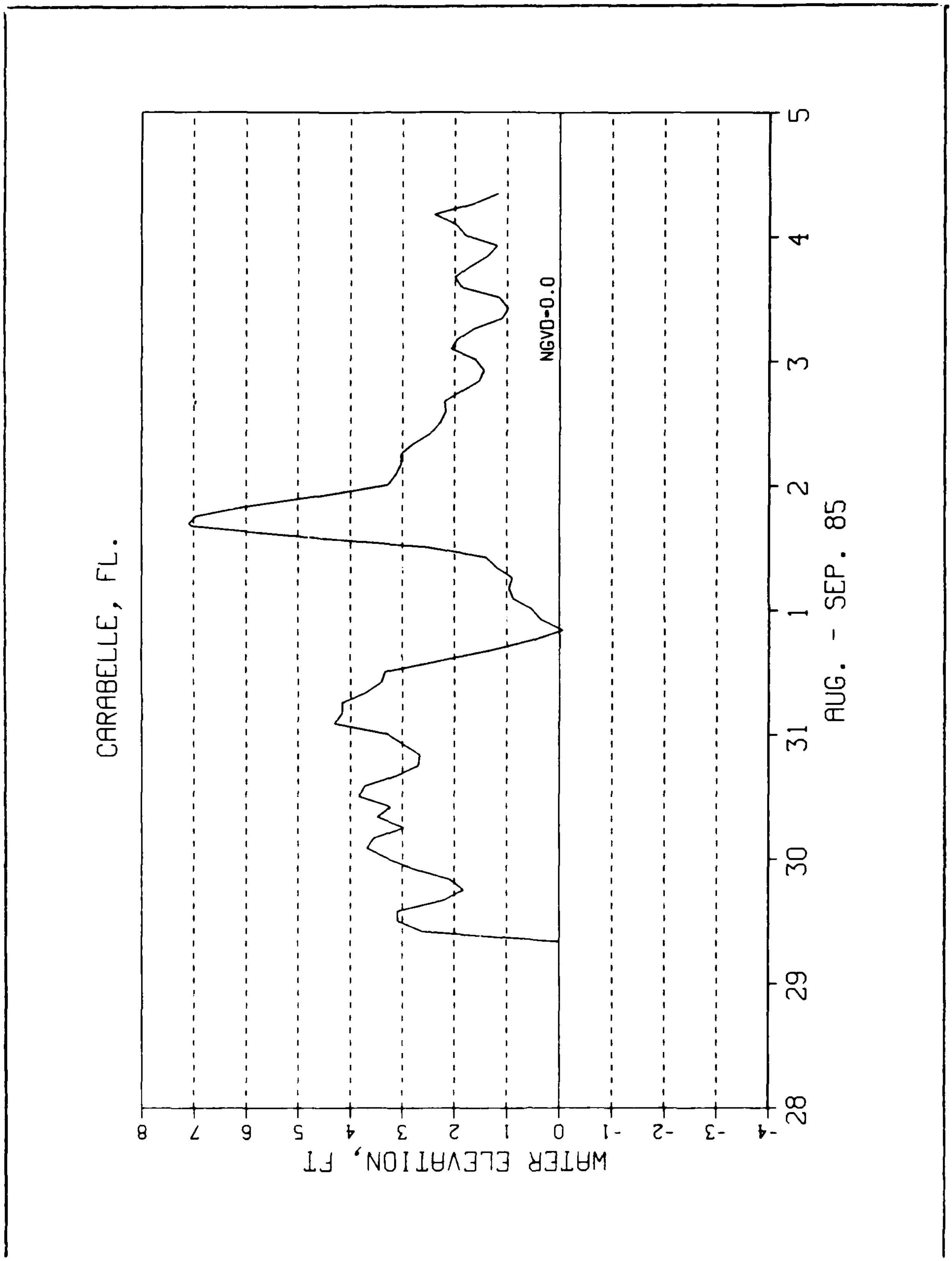
PLATE 14


PANAMA CITY, FL.
WATER ELEVATION, FT
NGVD=0.0
8 7 6 5 4 3 2 1 0 -1 -2 -3 -4
28 29 30 31 1 2 3 4 5
AUG. - SEP. 85



APALACHICOLA, FL.
NGVD-0.0
WATER ELEVATION, FT
8
7
6
5
4
3
2
1
0
-1
-2
-3
-4
28
29
30
31
1
2
3
4
5
AUG. - SEP. 85


PLATE 16


CARABELLE, FL.
AUG. - SEP. 85
WATER ELEVATION, FT
NGVD=0.0
28
29
30
31
1
2
3
4
5
-4
-3
-2
-1
0
1
2
3
4
5
6
7
8

## APPENDIX A: HIGH-WATER CONTOUR MAPS

This appendix contains a series of contour maps which are segments of US Geological Survey maps of the area. Most of the segments are taken from 1/24,000-scale maps with contour intervals of 5 ft. These segments cover an area approximately 2-1/2 miles by 3 miles. The remainder of the segments is taken from 1/62,500 scale maps with contour intervals of 10 ft. These segments cover an area approximately 6-1/2 by 8 miles. Each segment is labeled with the appropriate scale and contour interval. High-water marks, surveyed by the US Army Engineer District, Mobile, are plated on these maps. Not all maps contain a high-water mark but are included for reasons of continuity. The elevations of the high-water marks are included for reasons of continuity. The elevations of the high-water marks are labeled in feet above National Geodetic Vertical Datum and are denoted by a $\Delta$ symbol.

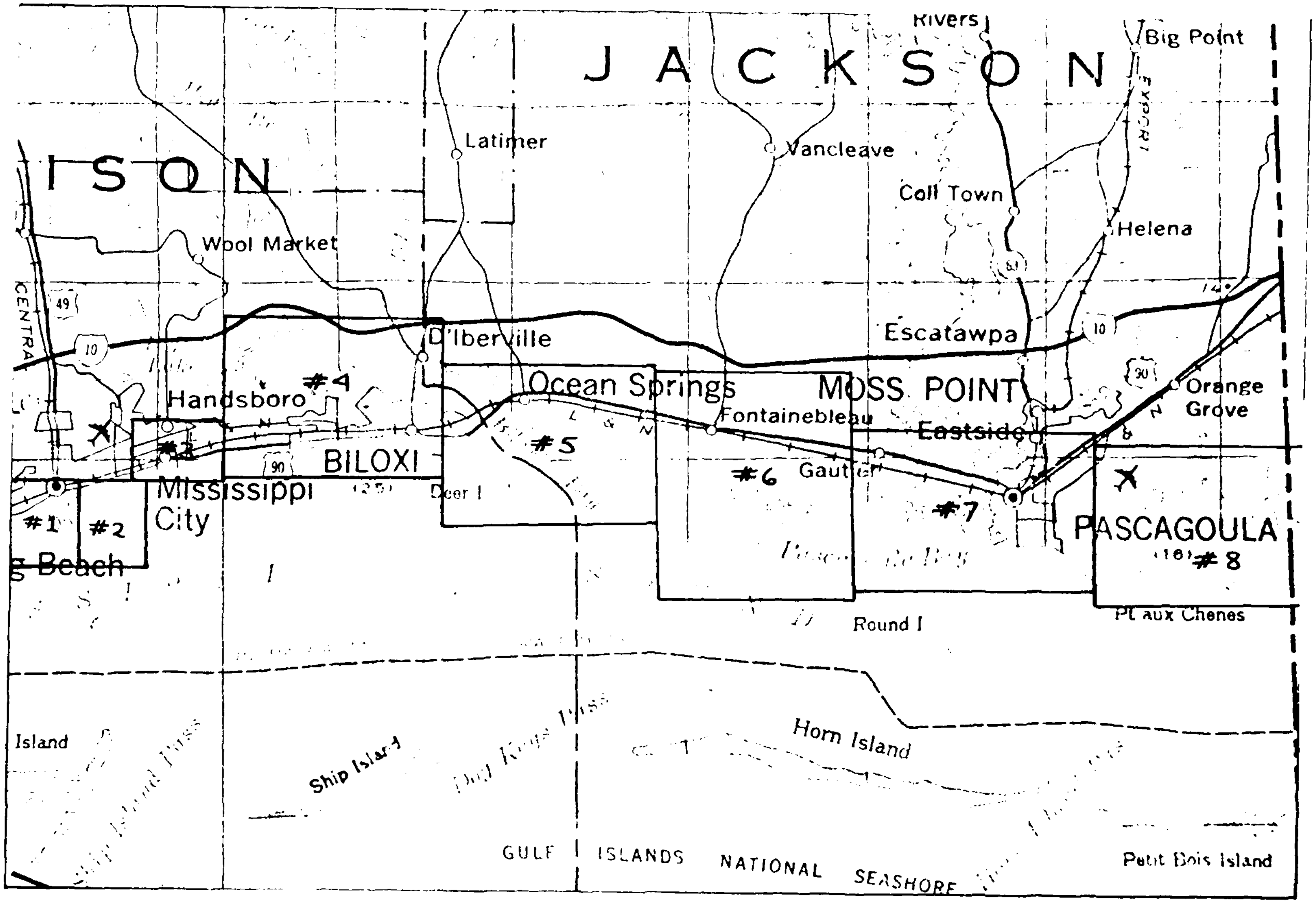



Figure A1. Index to high-water contour maps, segments 1-8

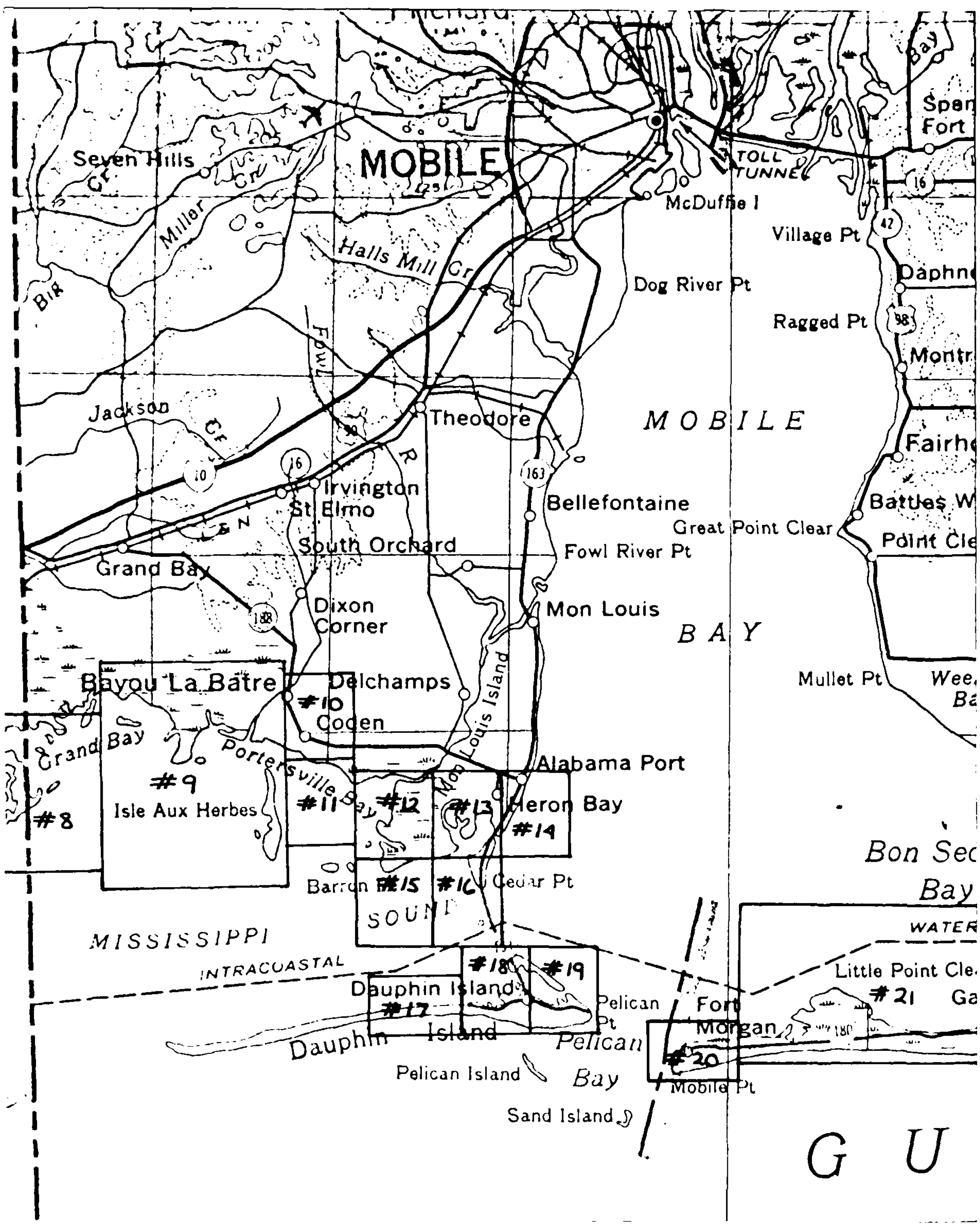



Figure A2. Index to high-water contour maps, segments 8-21

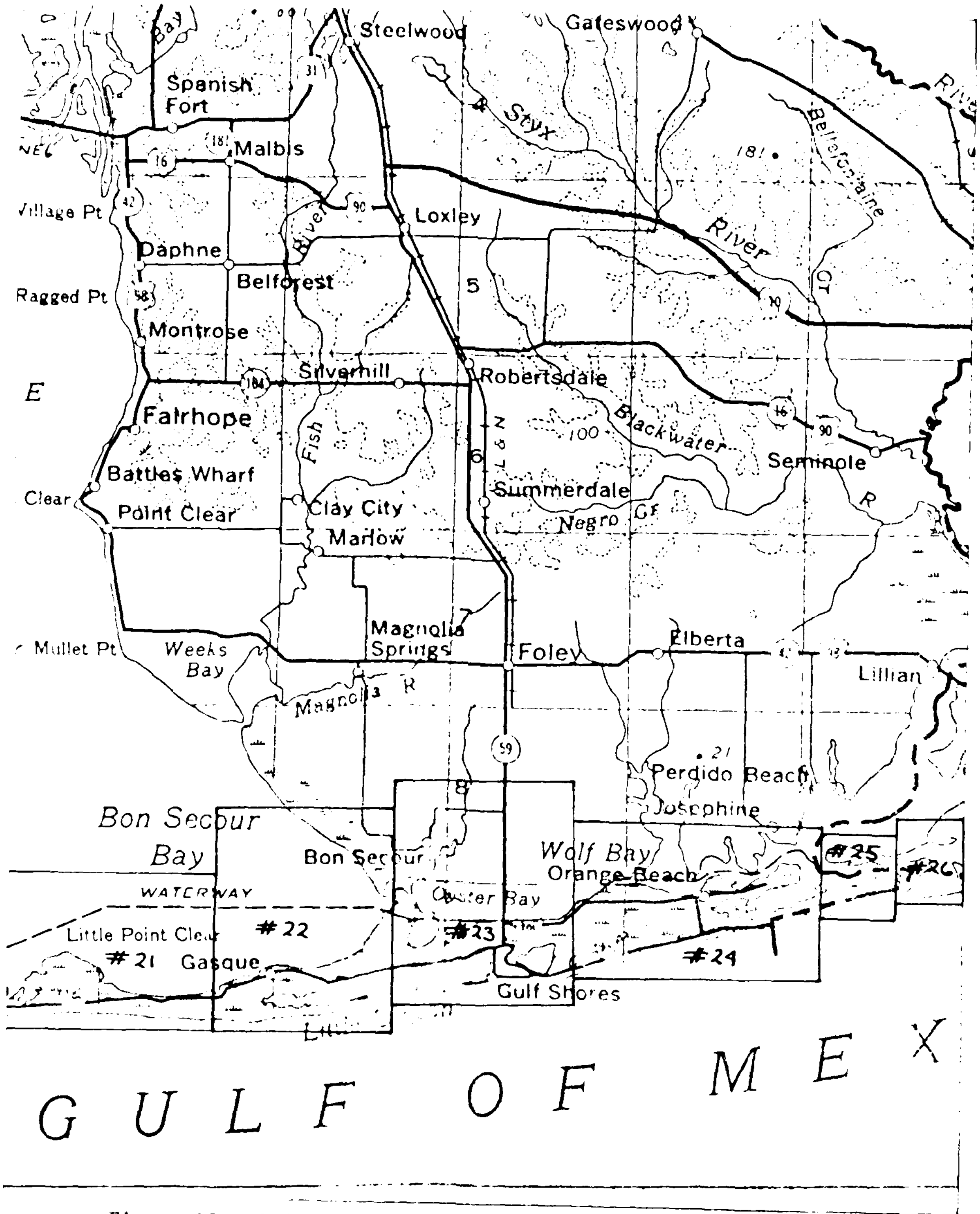



Figure A3. Index t( 'igh-water contour maps, segments 21-26

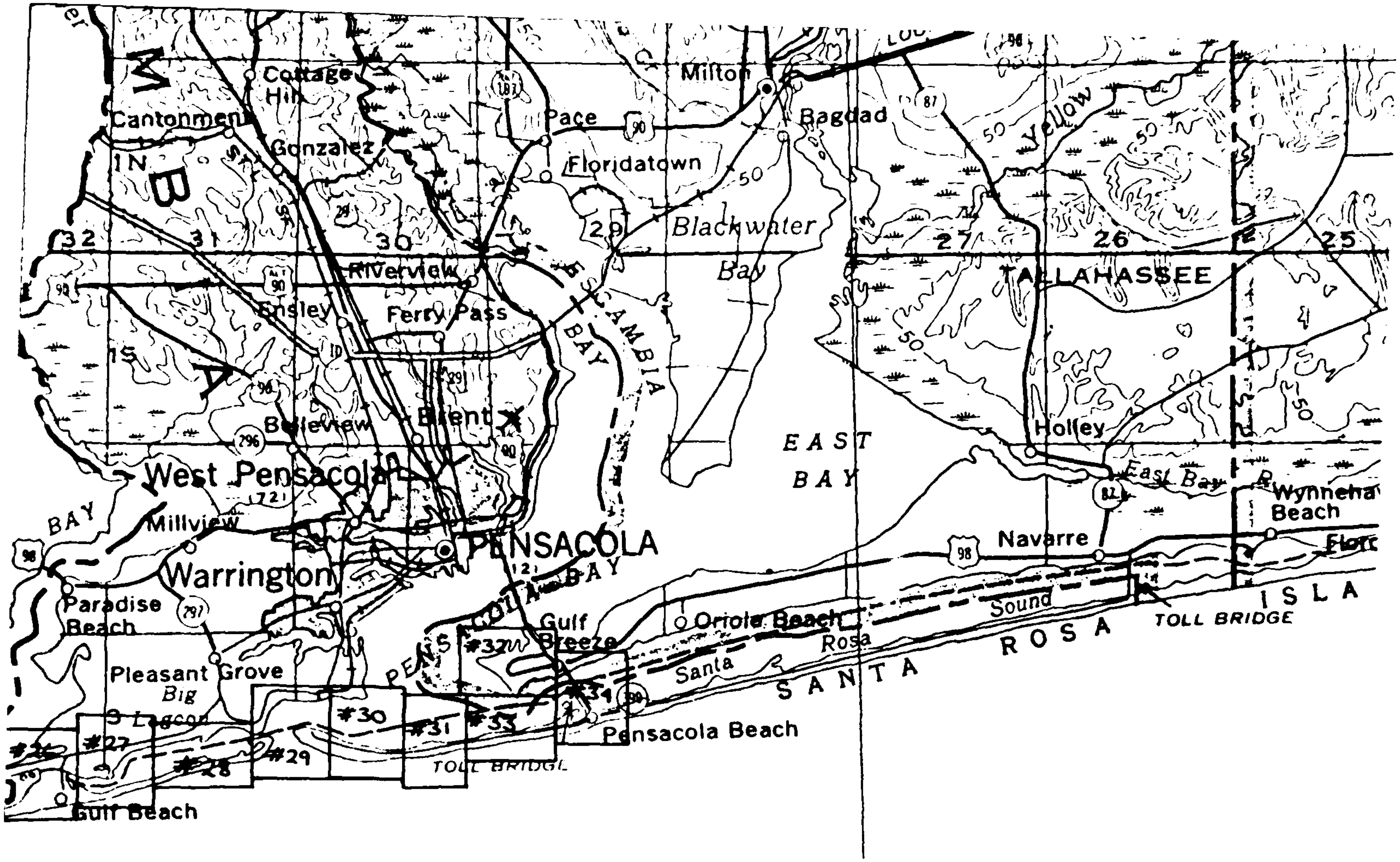



Figure A4. Index to high-water contour maps, segments 26-34

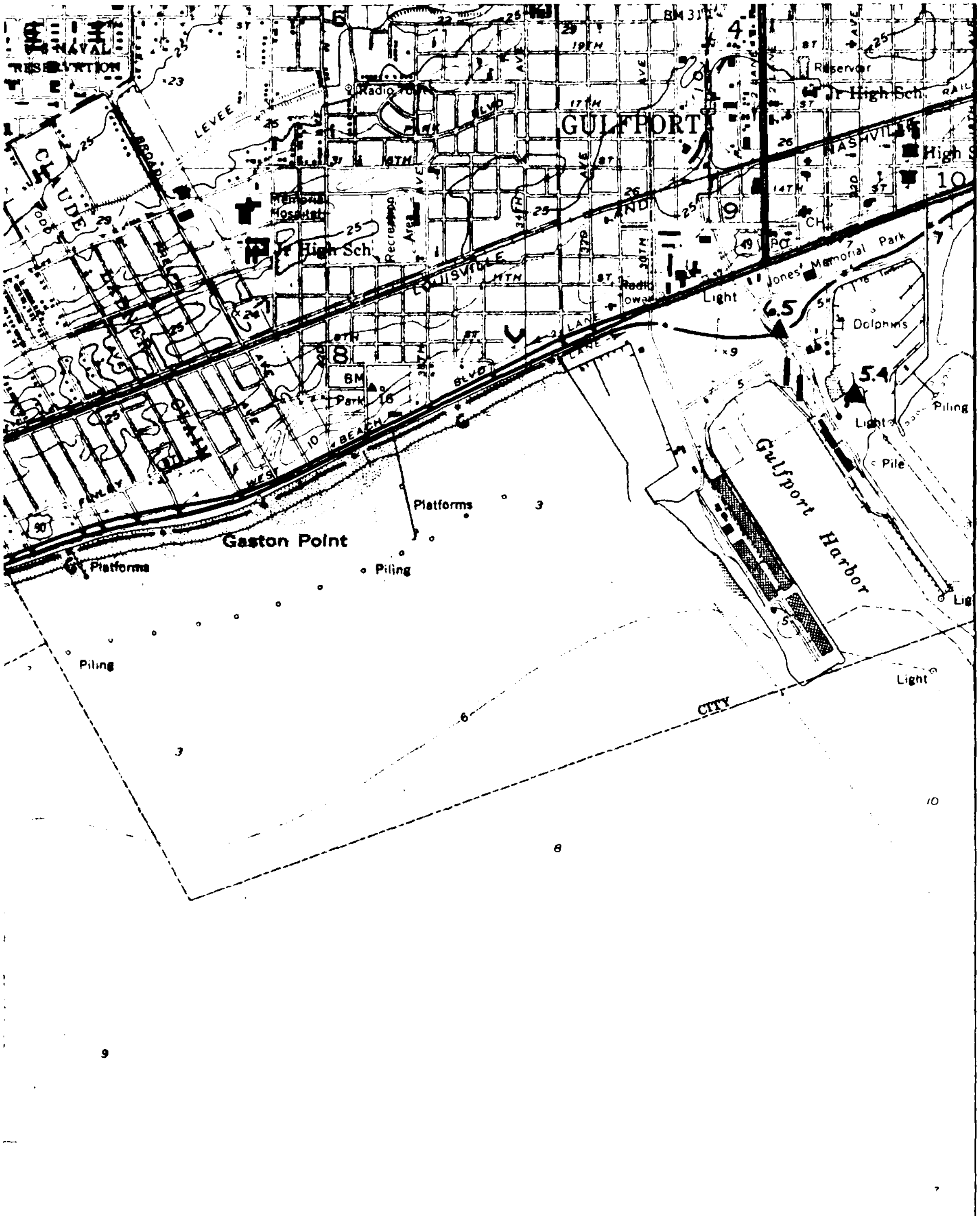



Figure A5. Segment 1, 1/24,000 scale, 5-ft contour interval

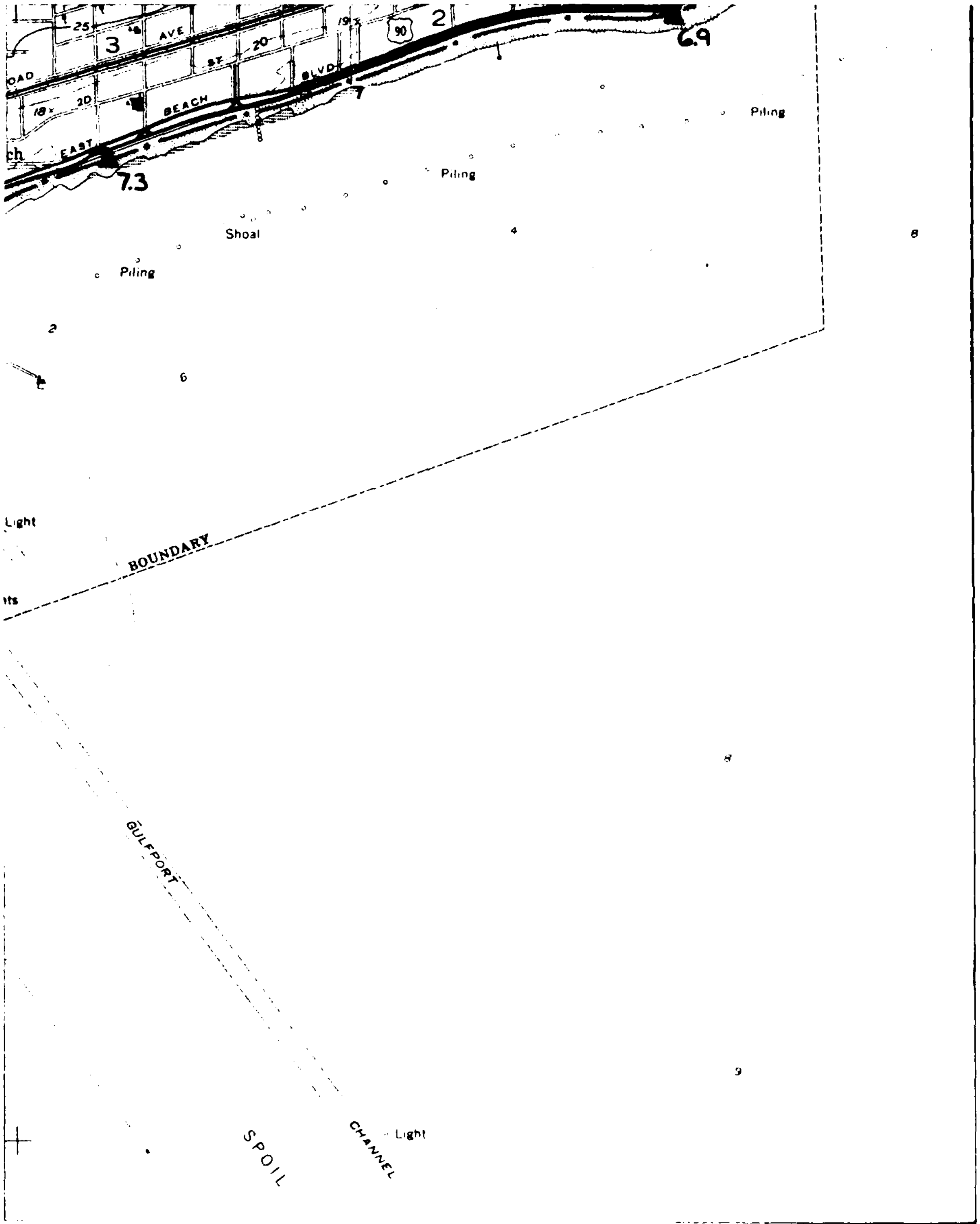



Figure A6. Segment 2, 1/24,000 scale, 5-ft contour interval

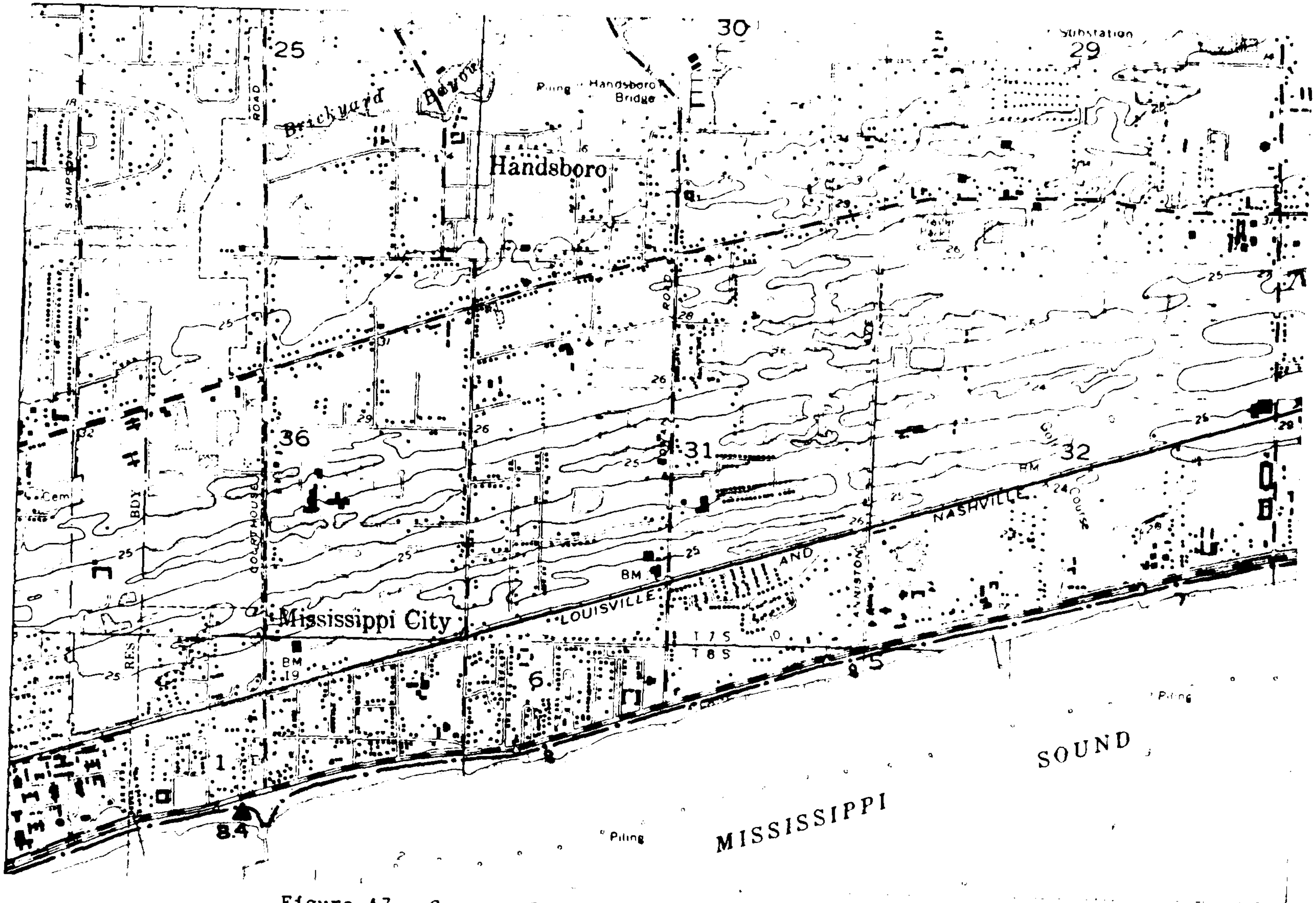



Figure A7. Segment 3, 1/24,000 scale, 5-ft contour interval

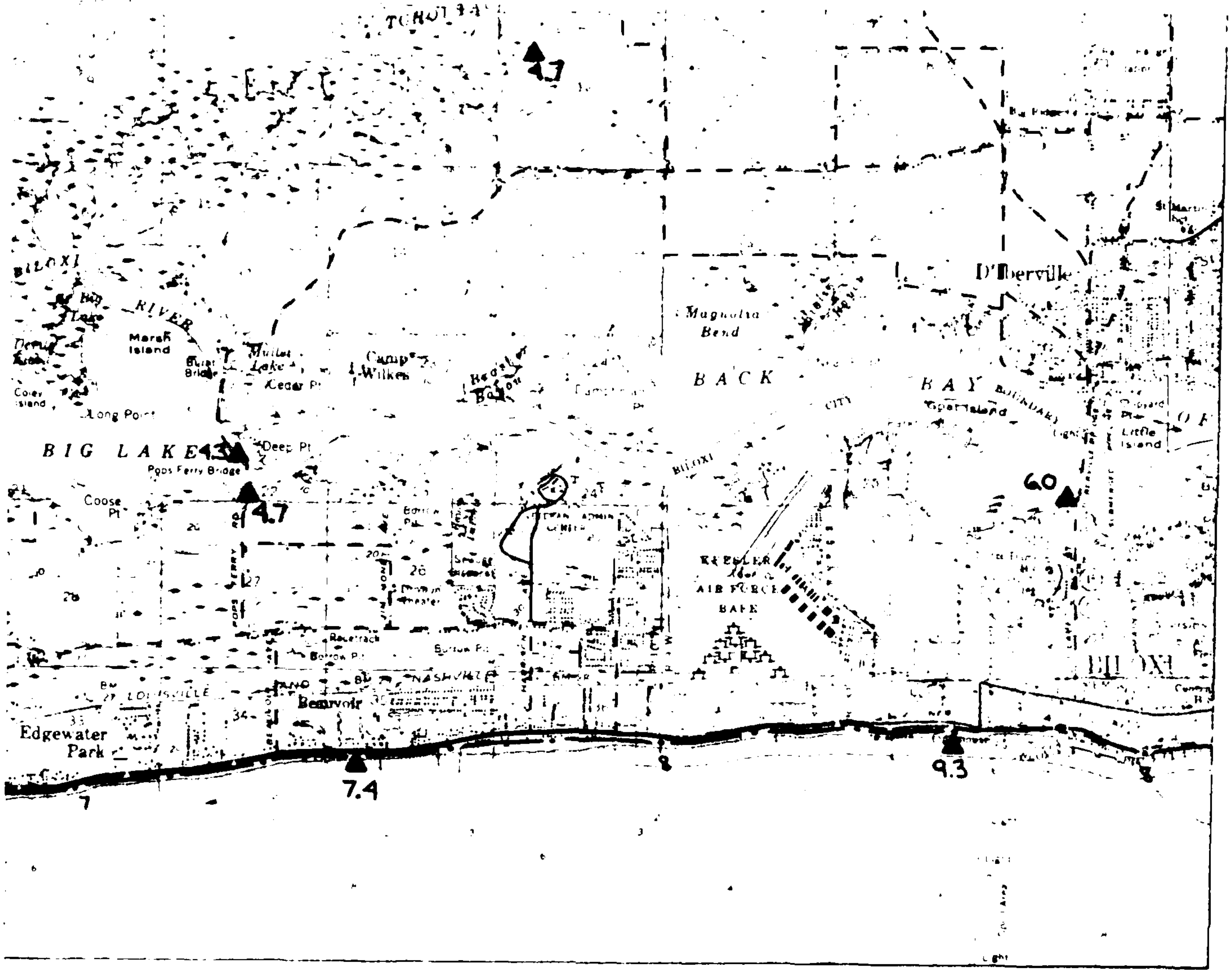



Figure A8. Segment 4, 1/62,500 scale, 10-ft contour interval

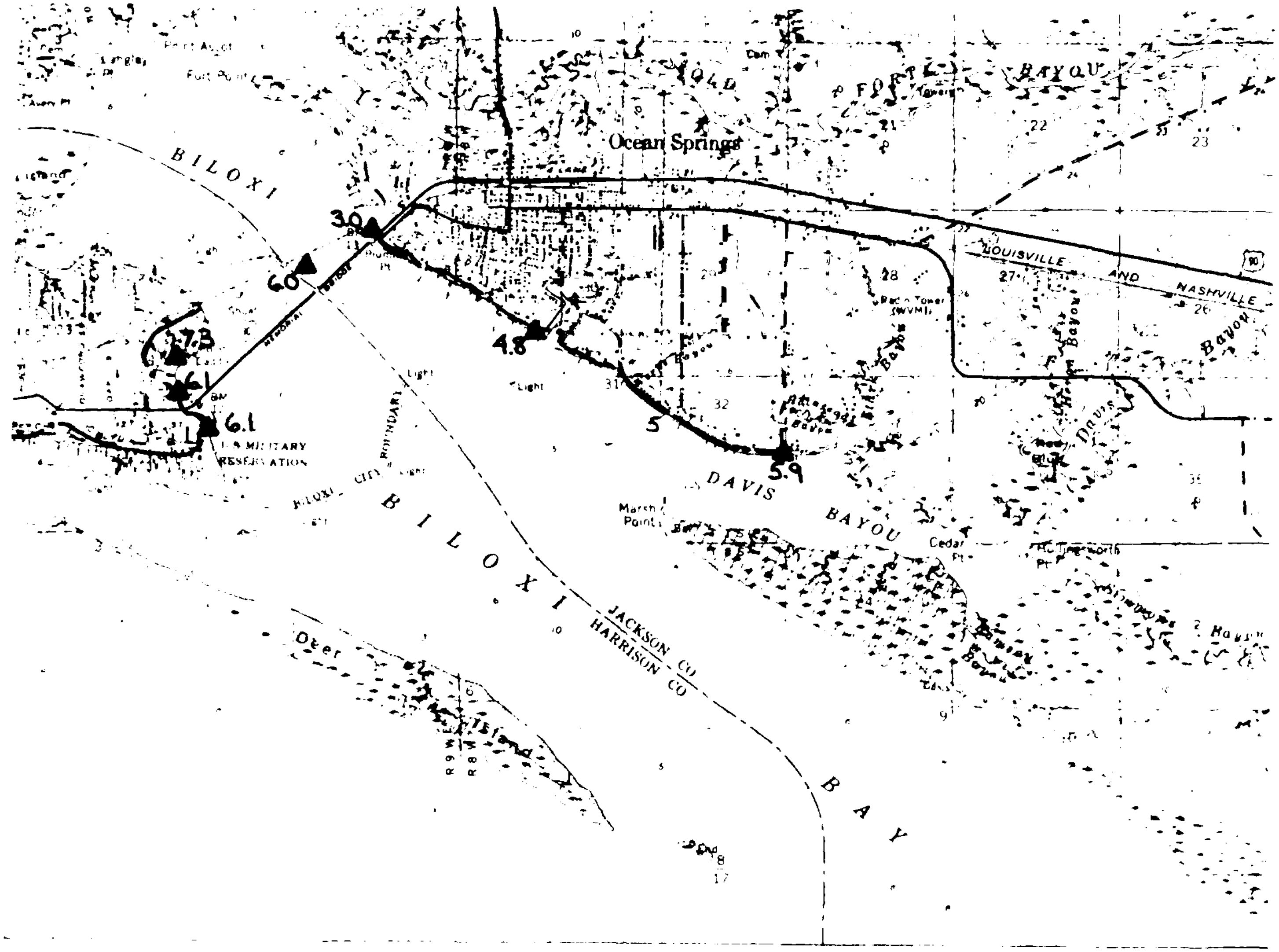



Figure A9. Segment 5, 1/62,500 scale, 10-ft contour interval

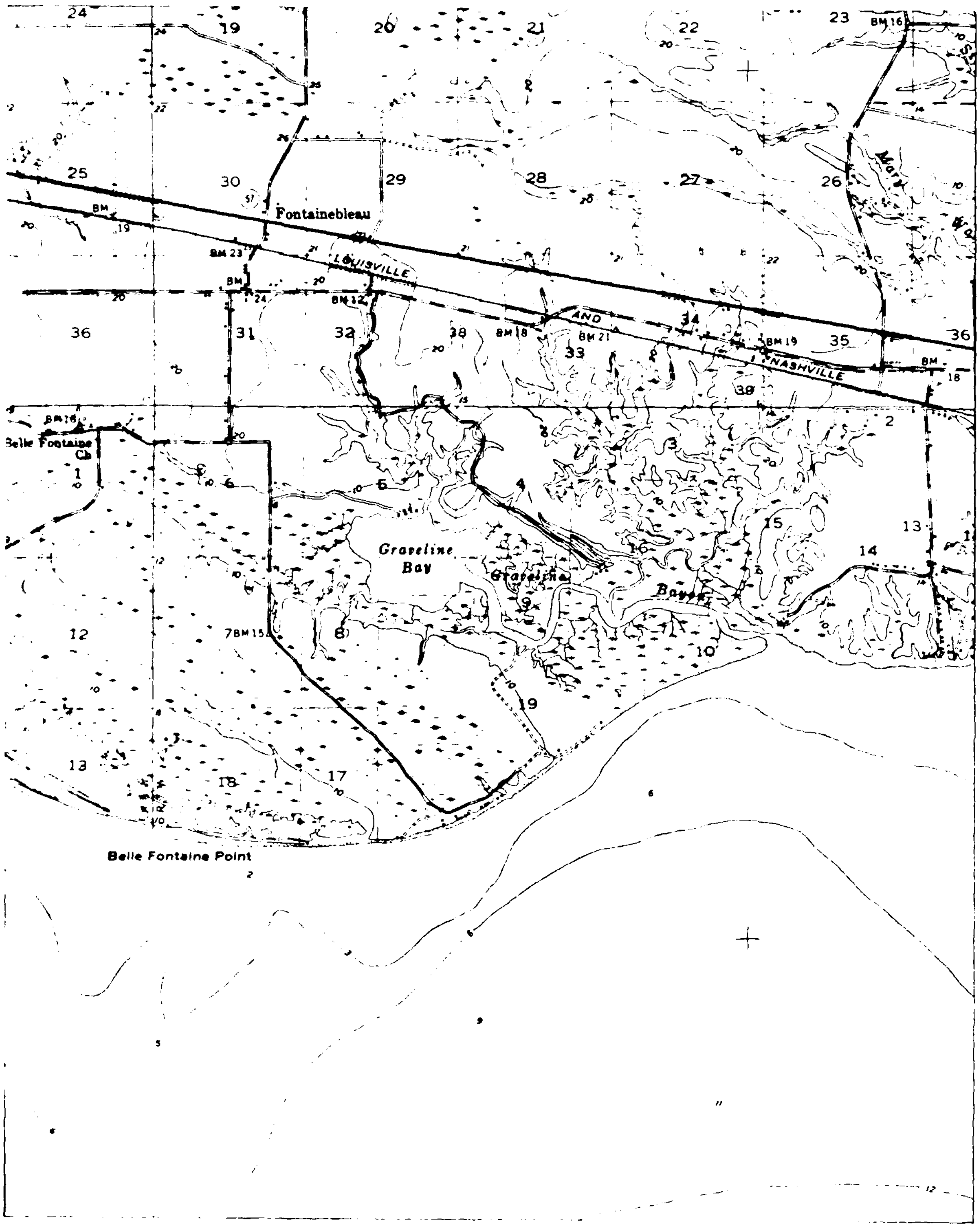



Figure A10. Segment 6, 1/62,000 scale, 10-ft contour interval

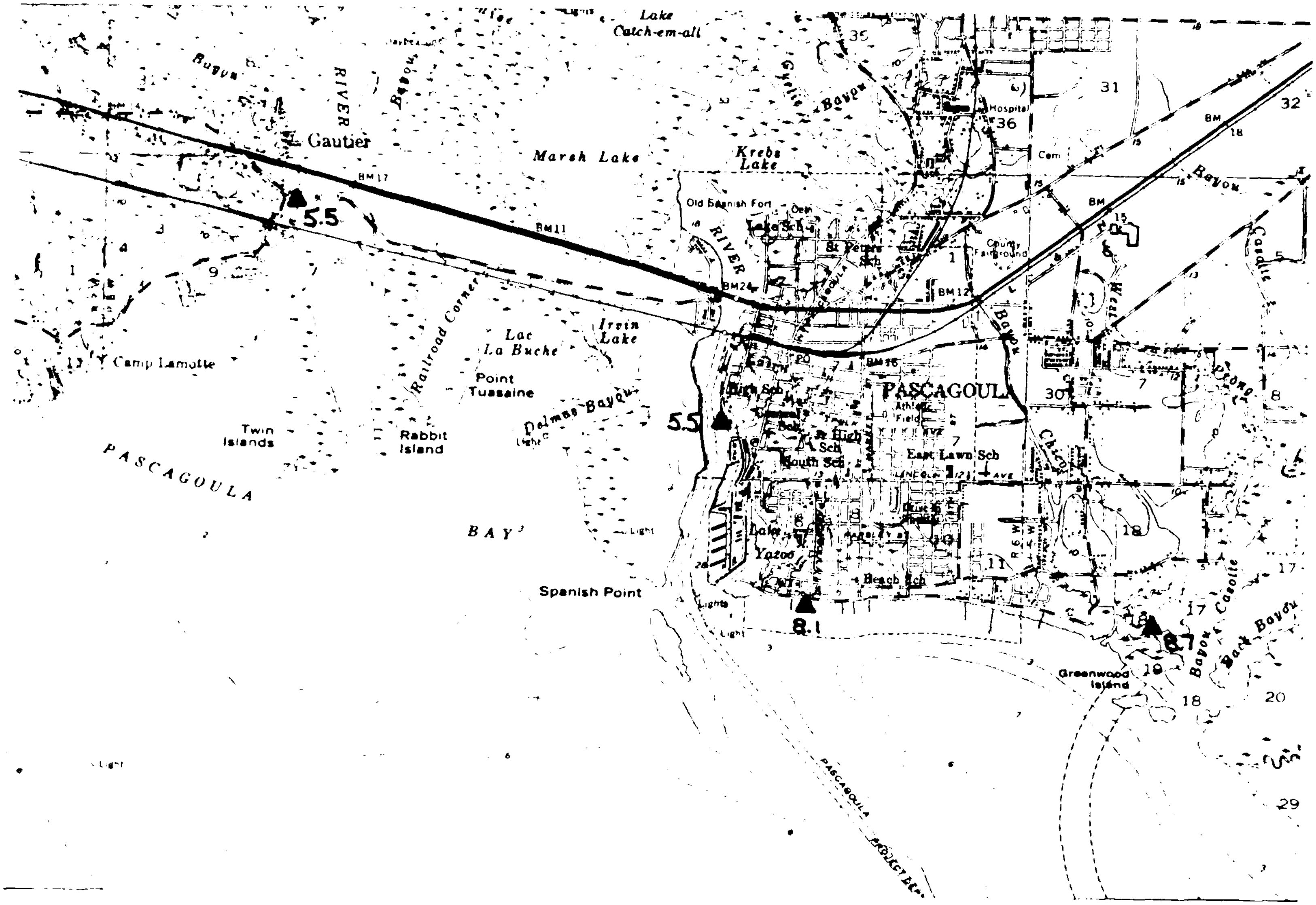



Figure A11. Segment 7, 1/62,500 scale, 10-ft contour interval

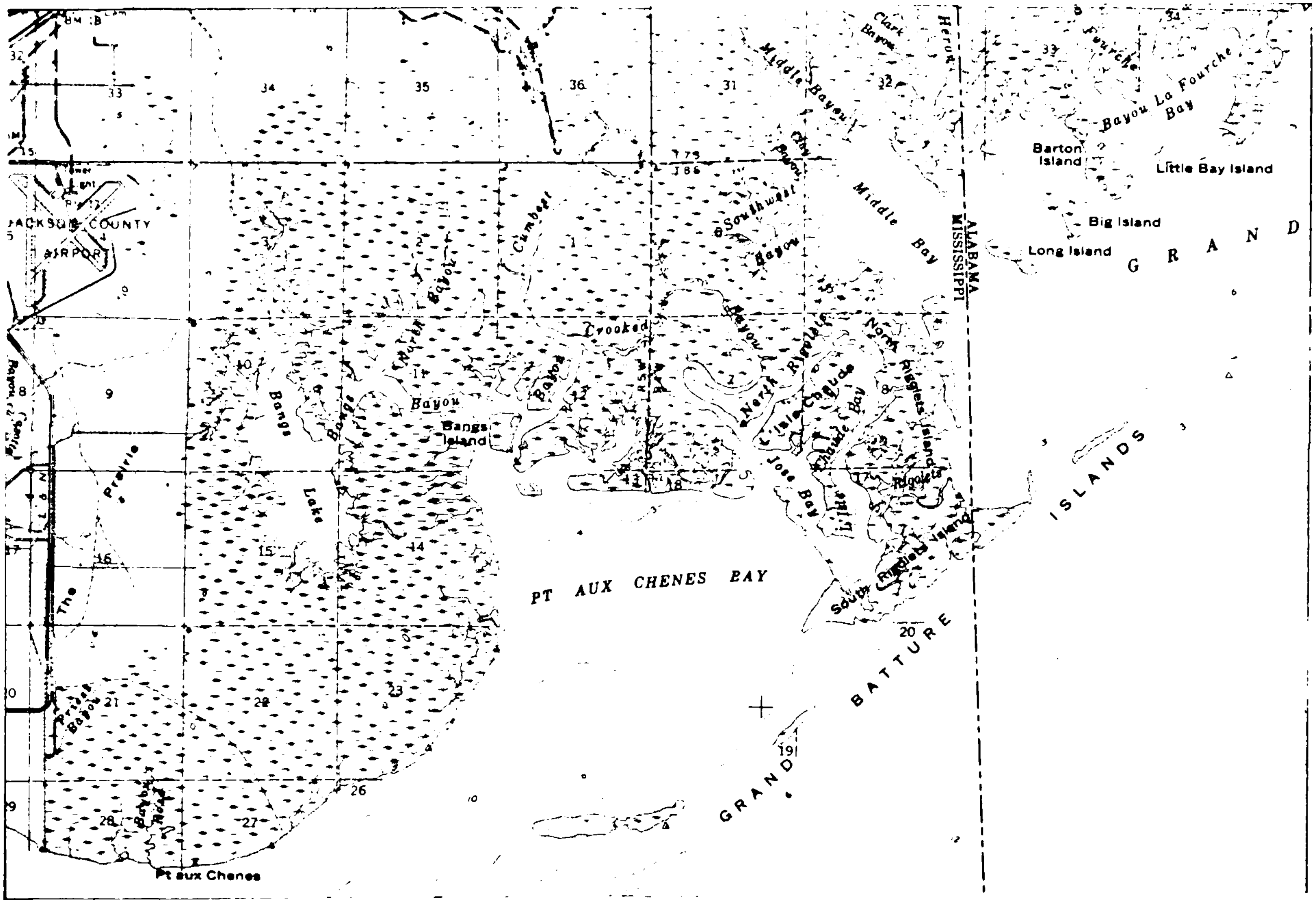



Figure A12. Segment 8, 1/62,500 scale, 10-ft contour interval

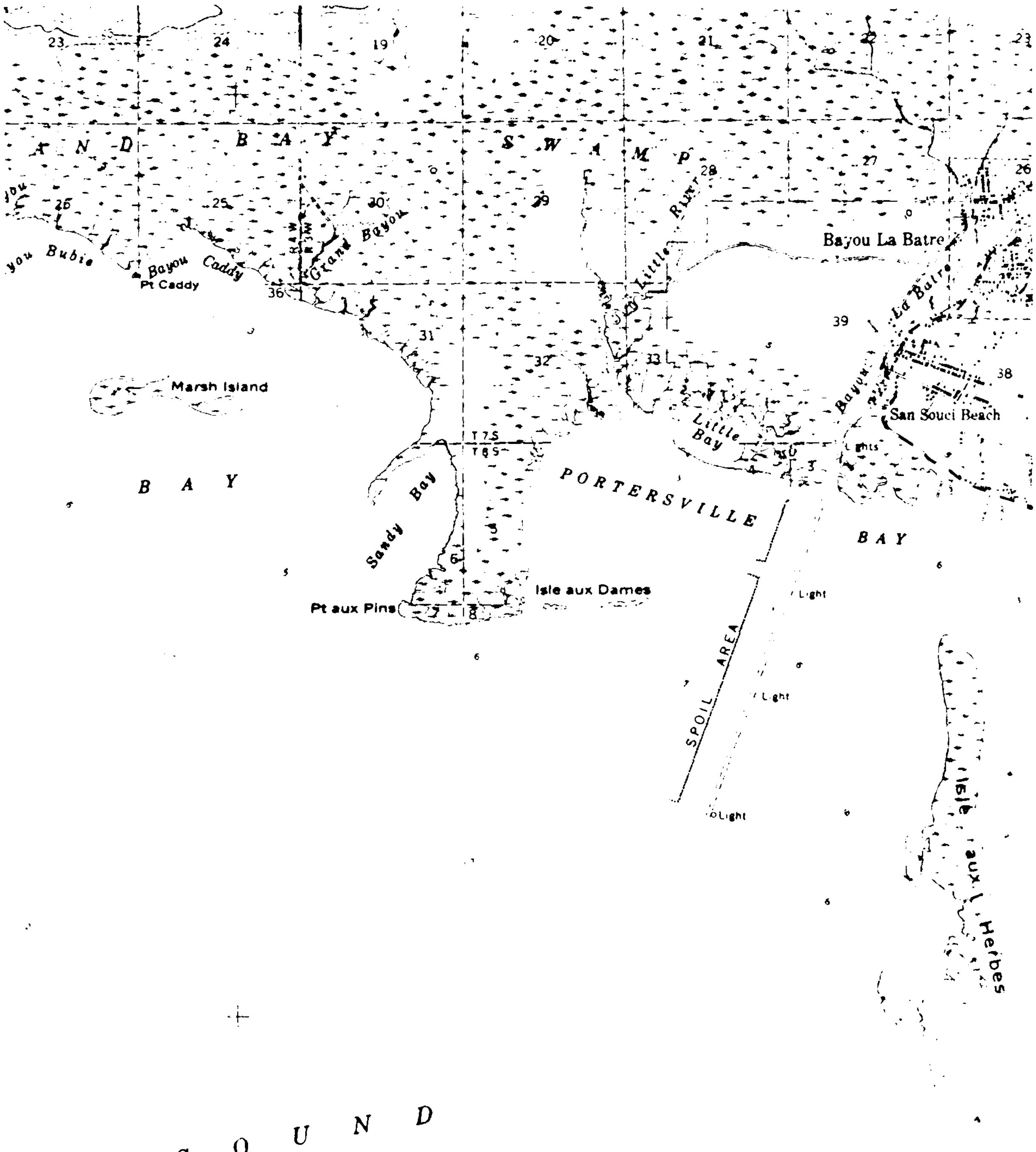



Figure A13. Segment 9, 1/62,500 scale, 10-ft contour interval

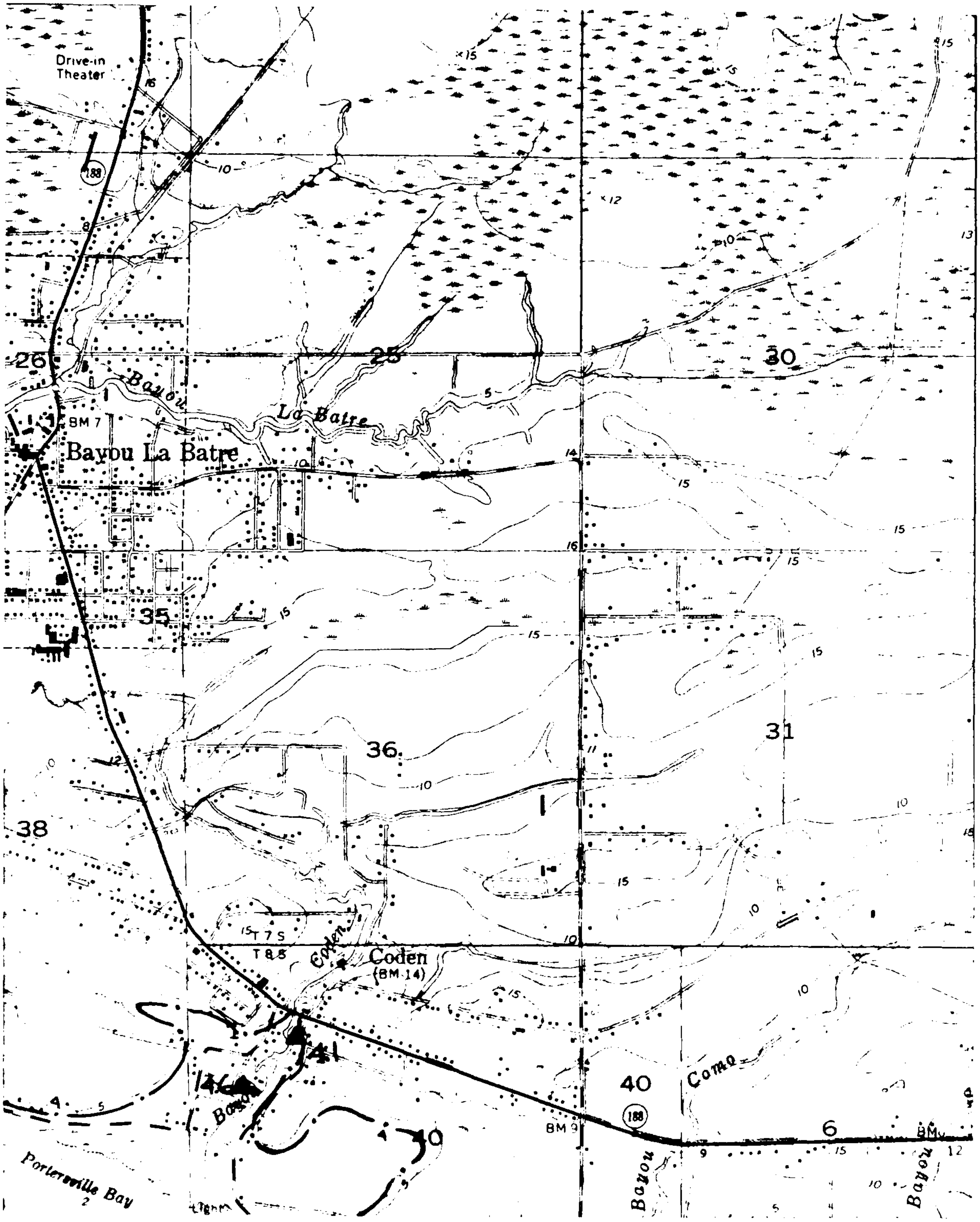



Figure A14. Segment 10, 1/24,000 scale, 5-ft contour interval

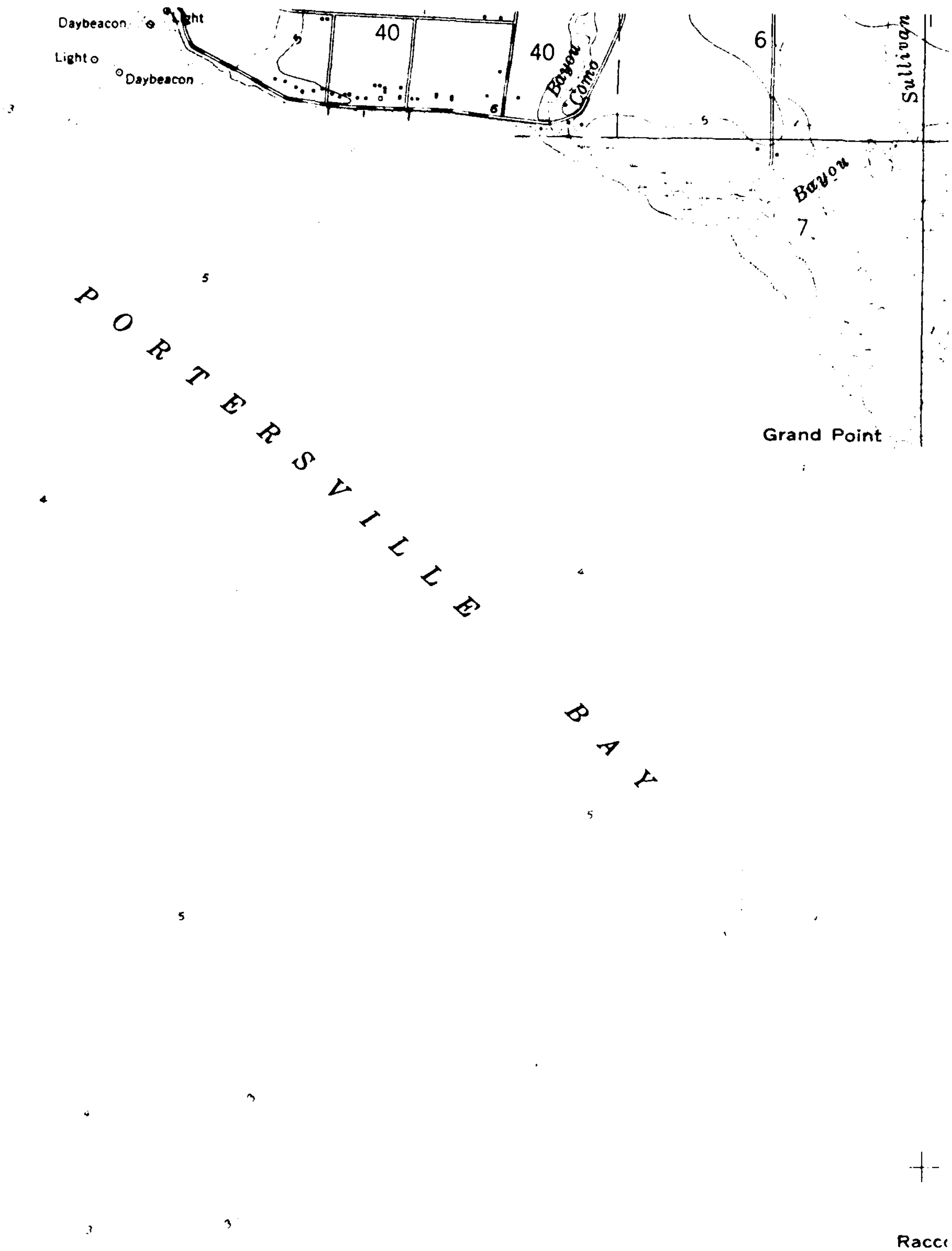



Figure A15. Segment 11, 1/24,000 scale, 5-ft contour interval

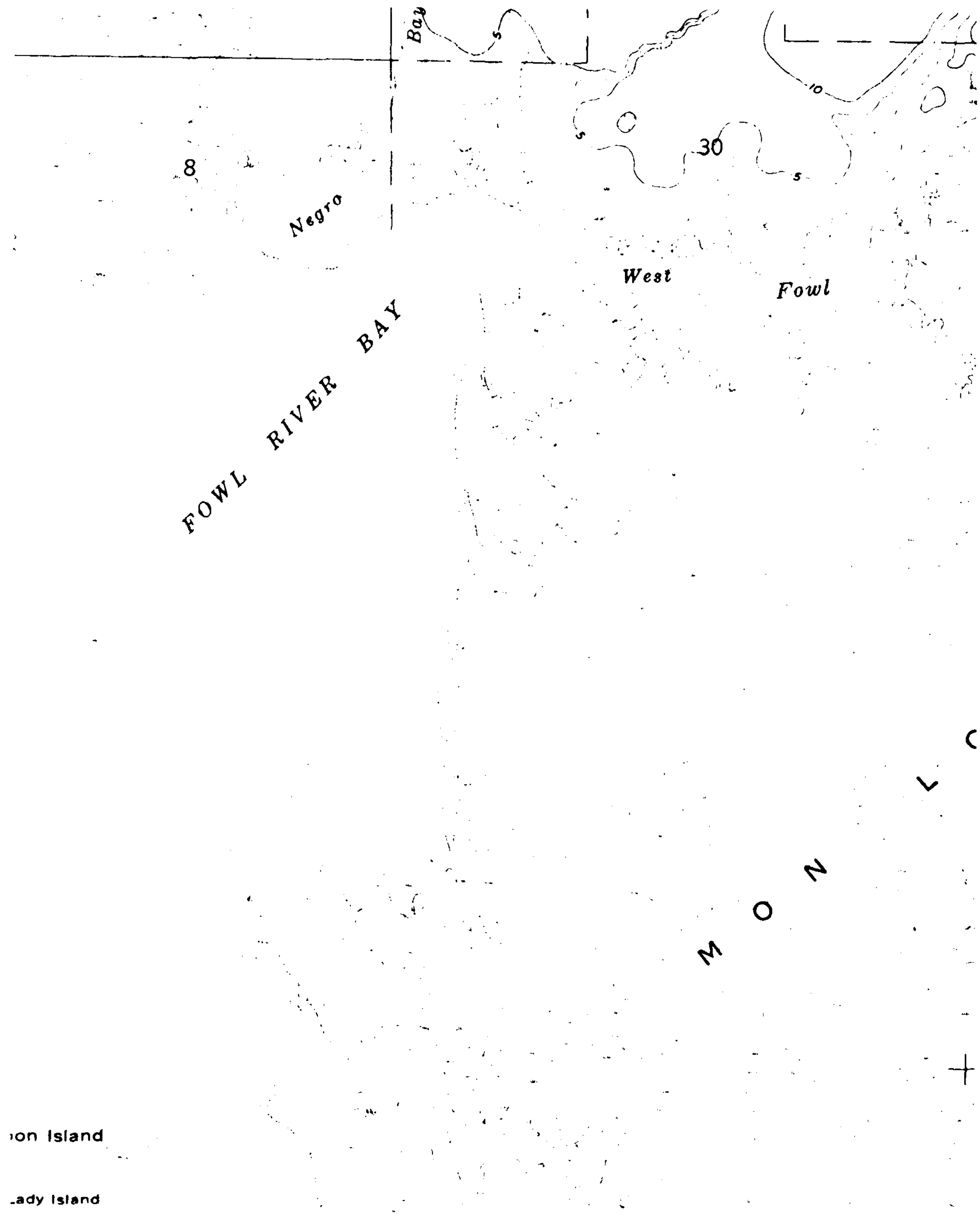



Figure A16. Segment 12, 1/24,000 scale, 5-ft contour interval

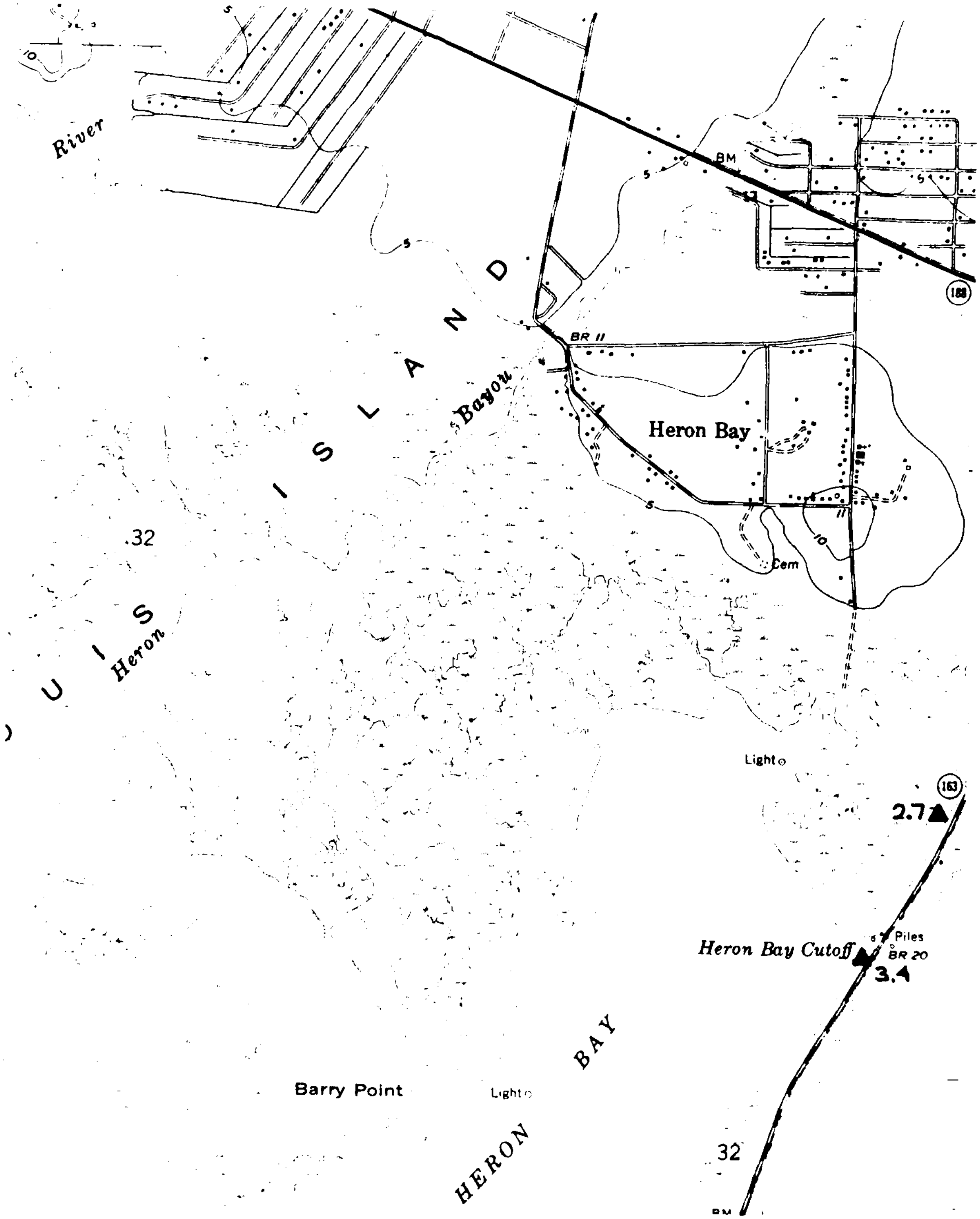



Figure A17. Segment 13, 1/24,000 scale, 5-ft contour interval

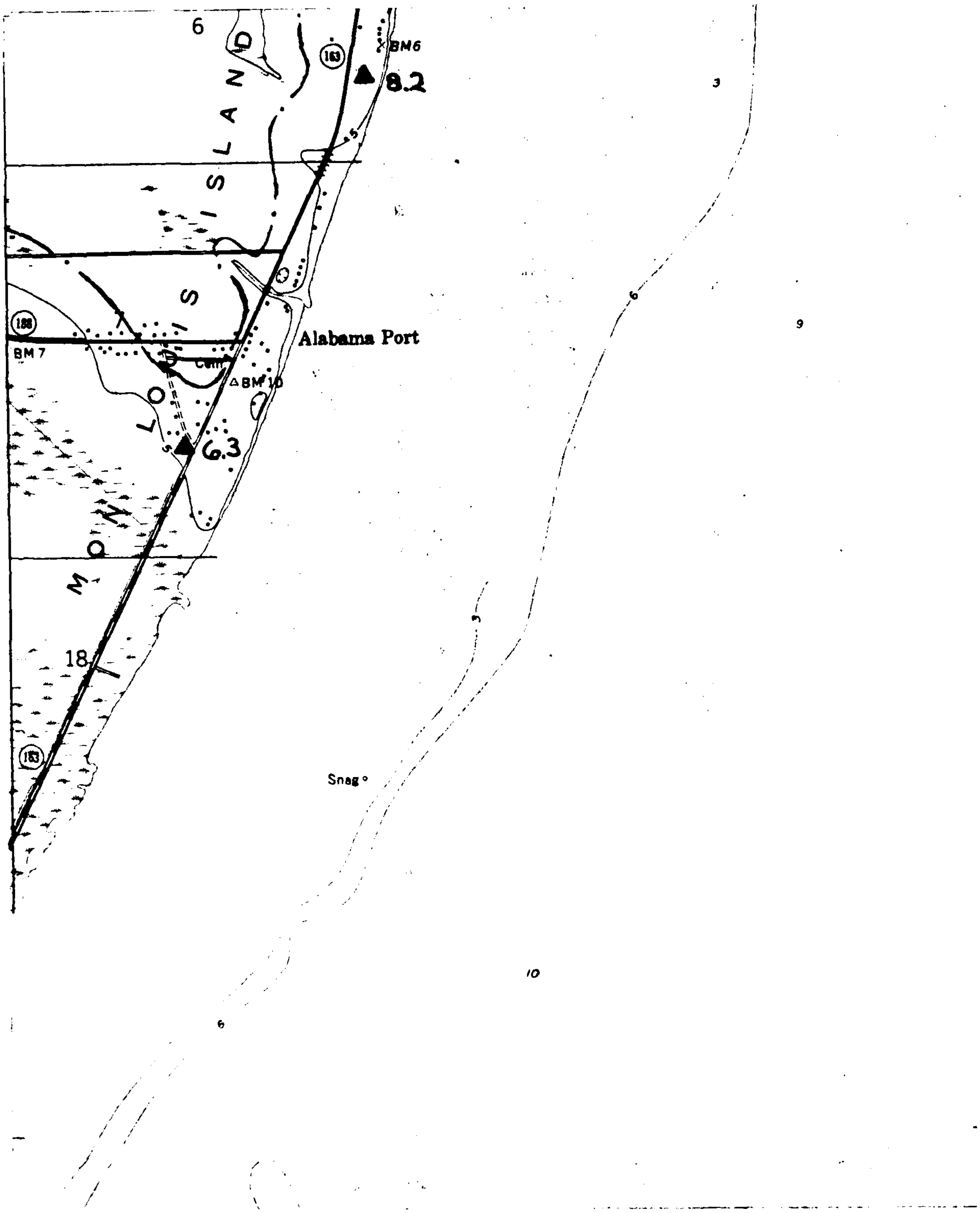



Figure A18. Segment 14, 1/24,000 scale, 5-ft contour interval

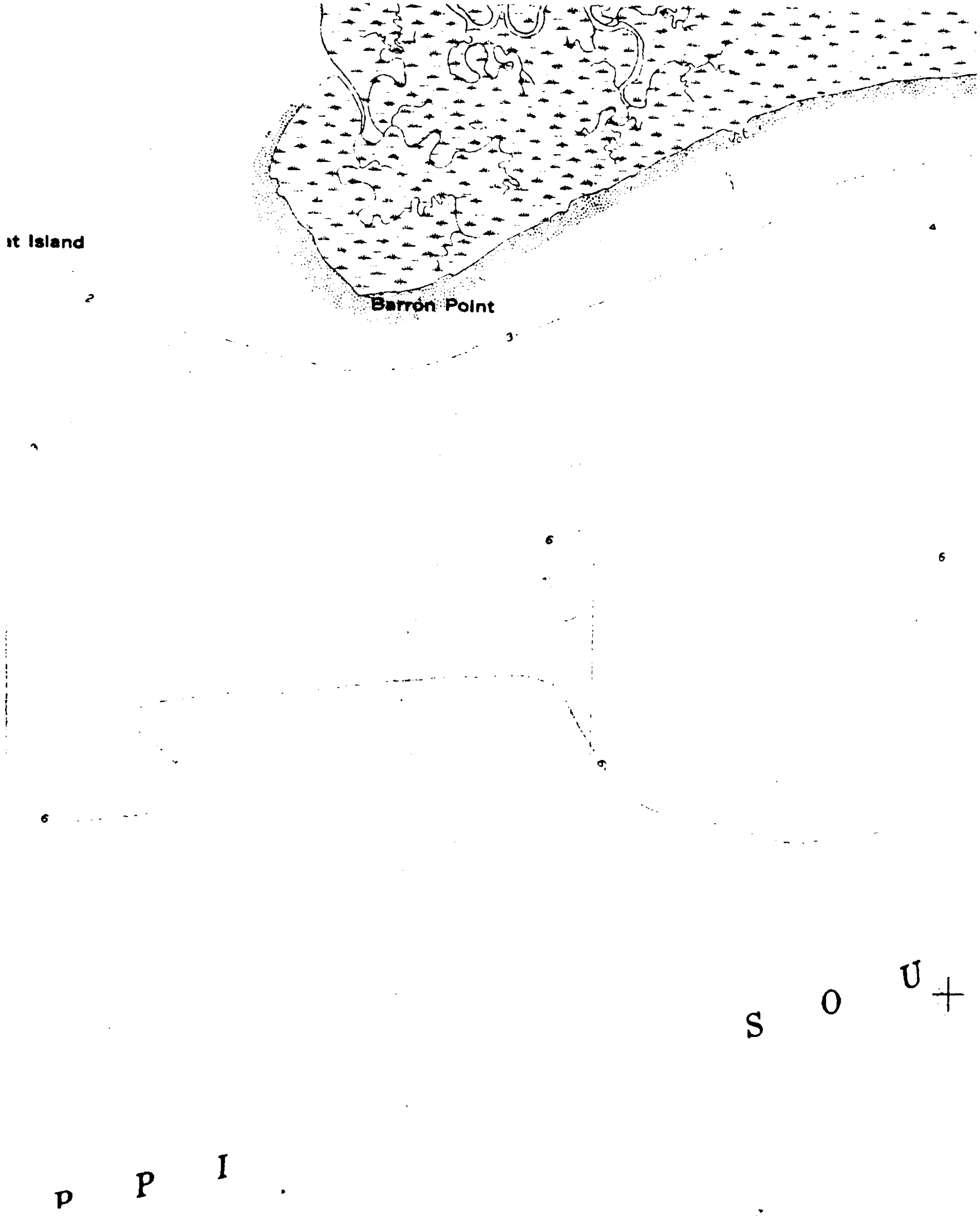



Figure A19. Segment 15, 1/24,000 scale, 5-ft contour interval

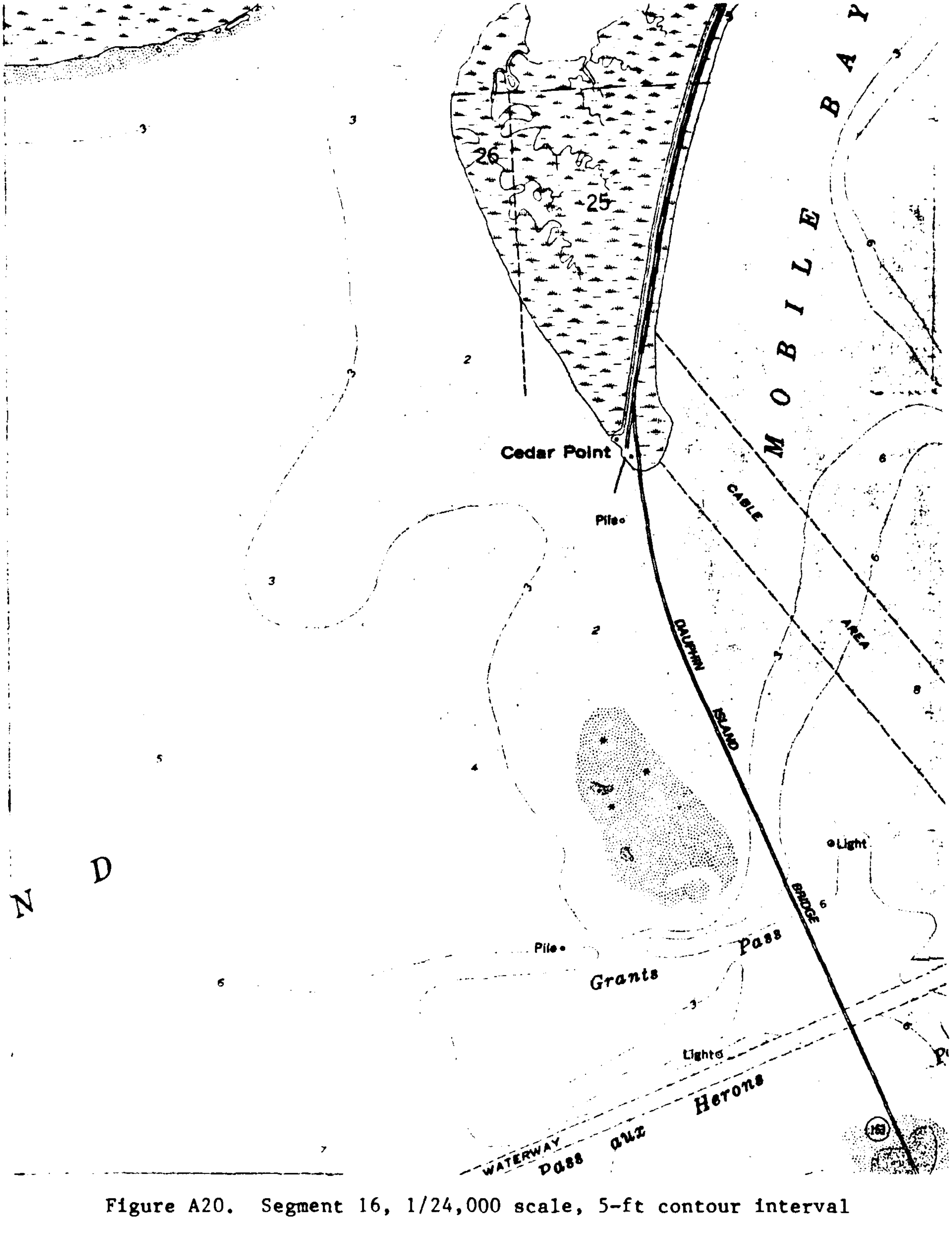



Figure A20. Segment 16, 1/24,000 scale, 5-ft contour interval

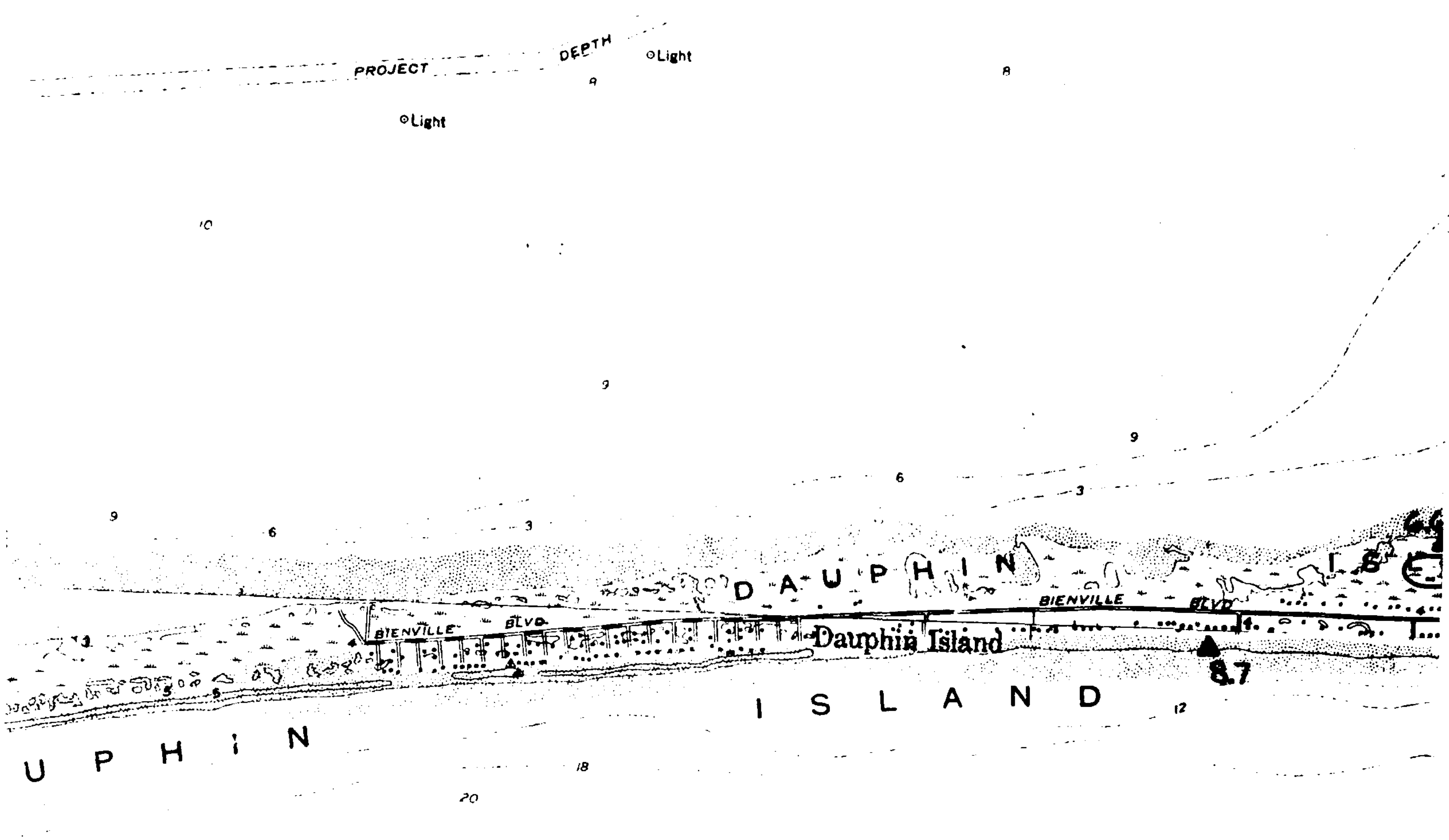



Figure A21. Segment 17, 1/24,000 scale, 5-ft contour interval

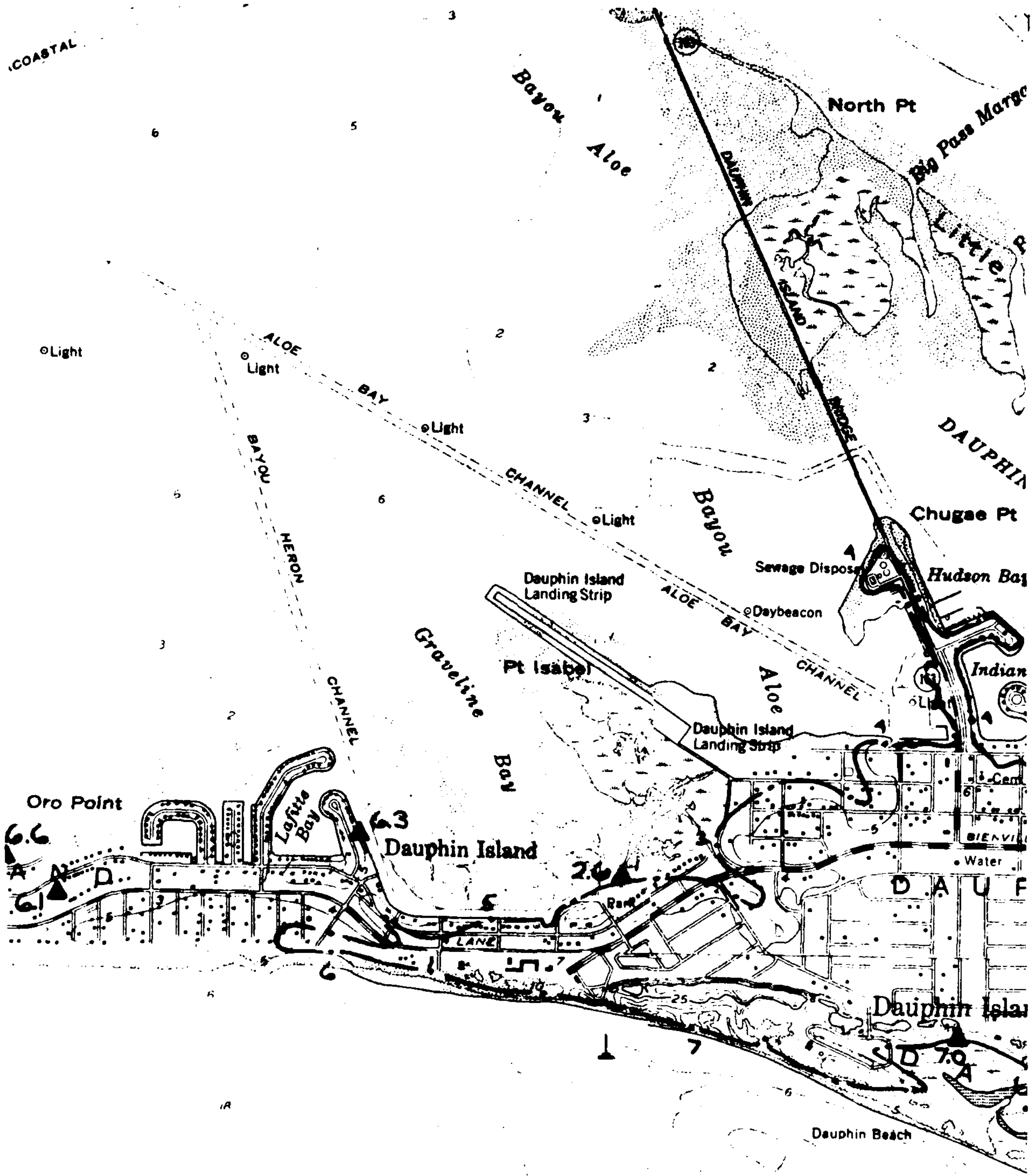



Figure A22. Segment 18, 1/24,000 scale, 5-ft contour interval

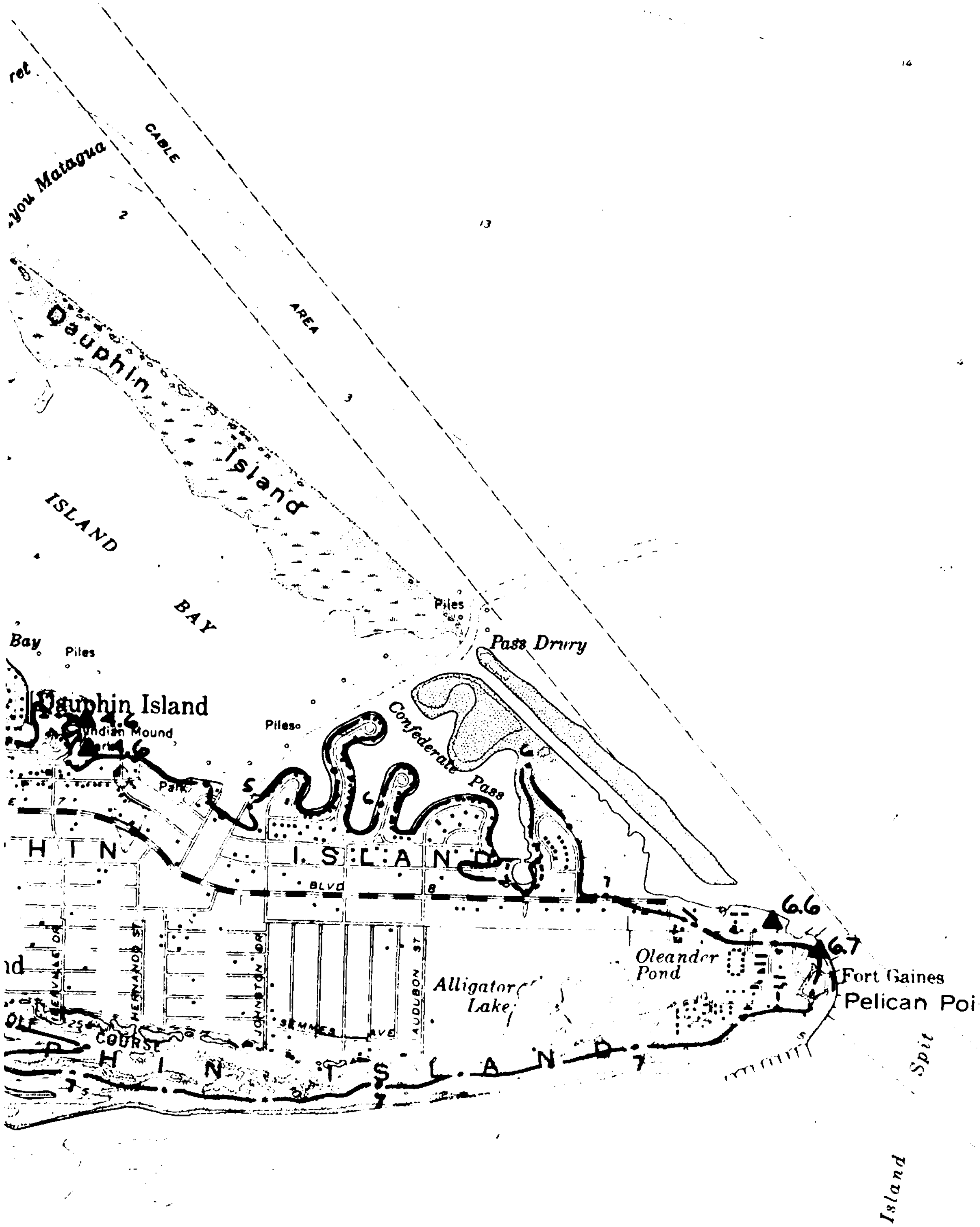



Figure A23. Segment 19, 1/24,000 scale, 5-ft contour interval

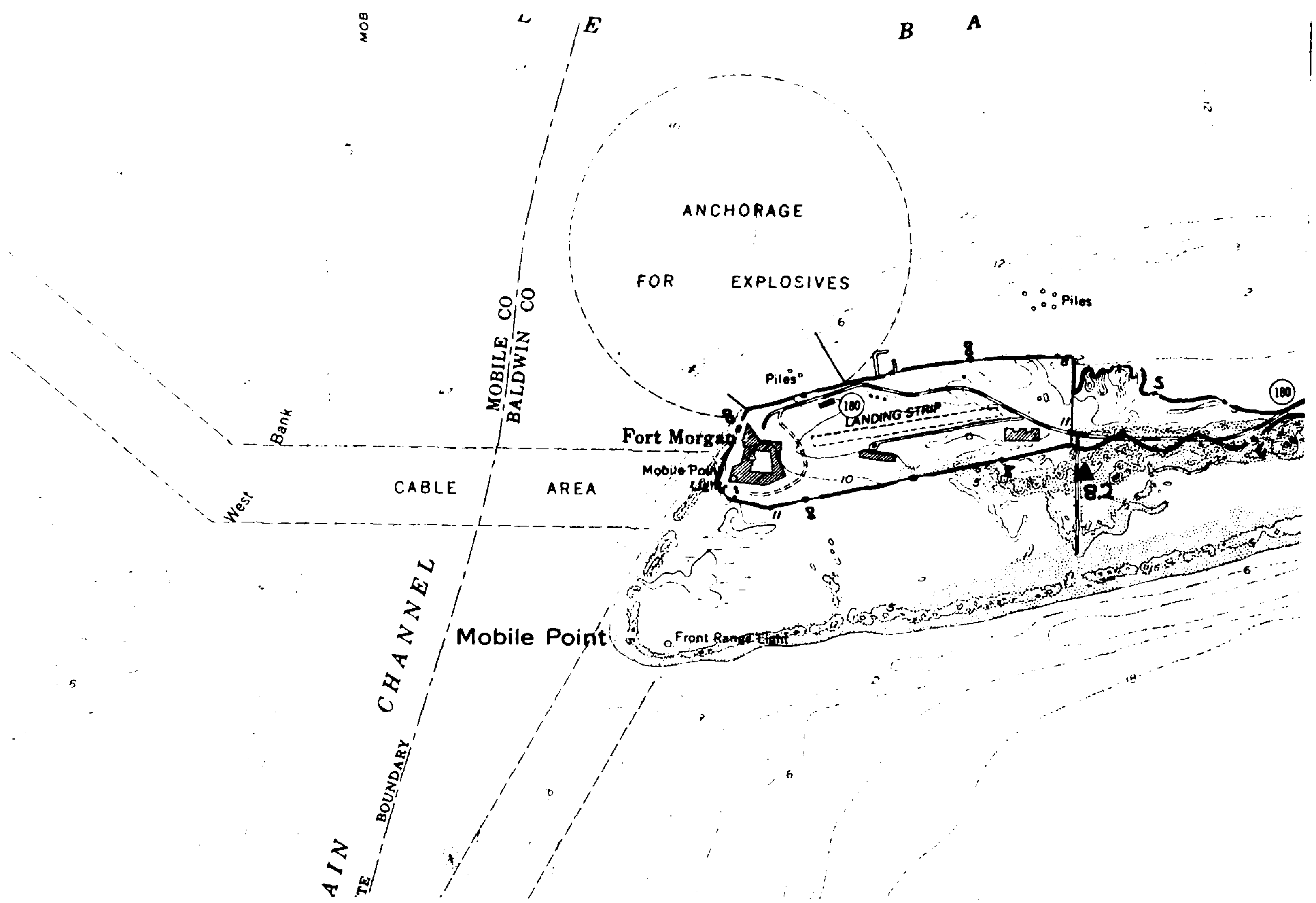



Figure A24. Segment 20, 1/24,000 scale, 5-ft contour interval

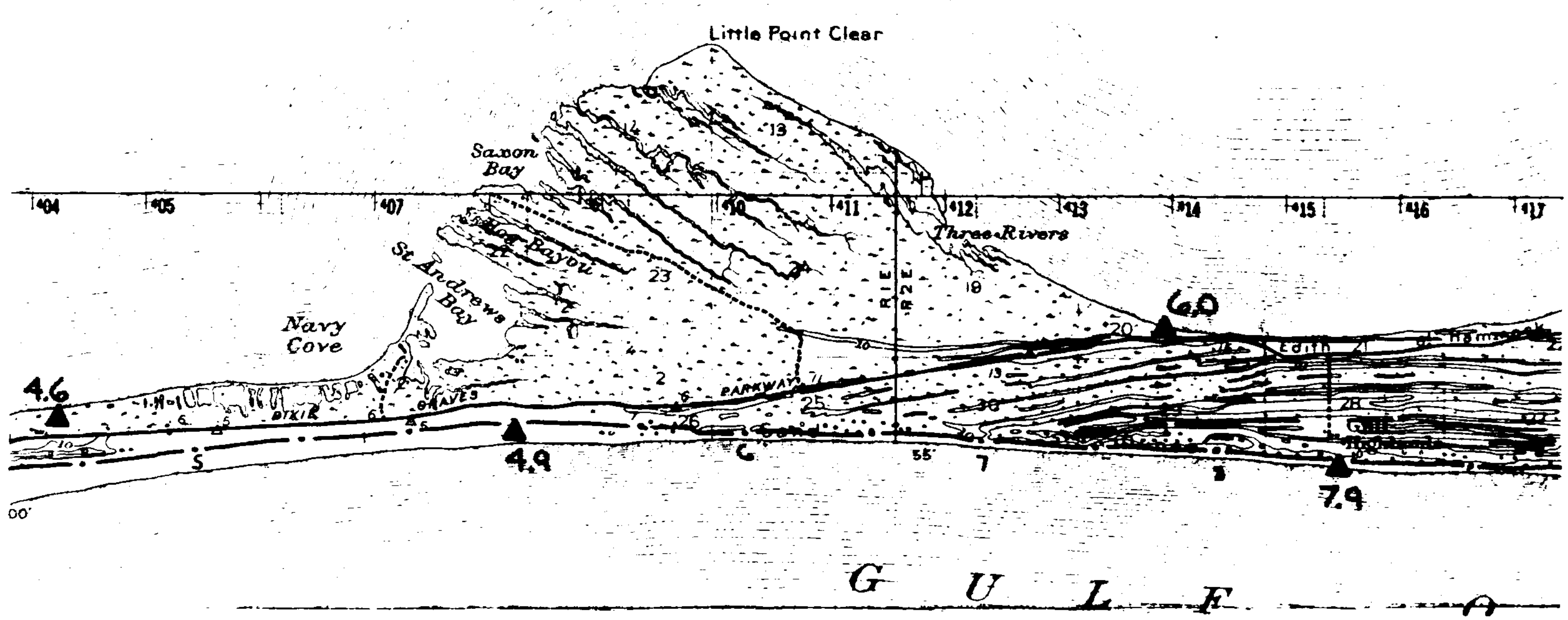



Figure A25. Segment 21, 1/62,500 scale, 10-ft contour interval

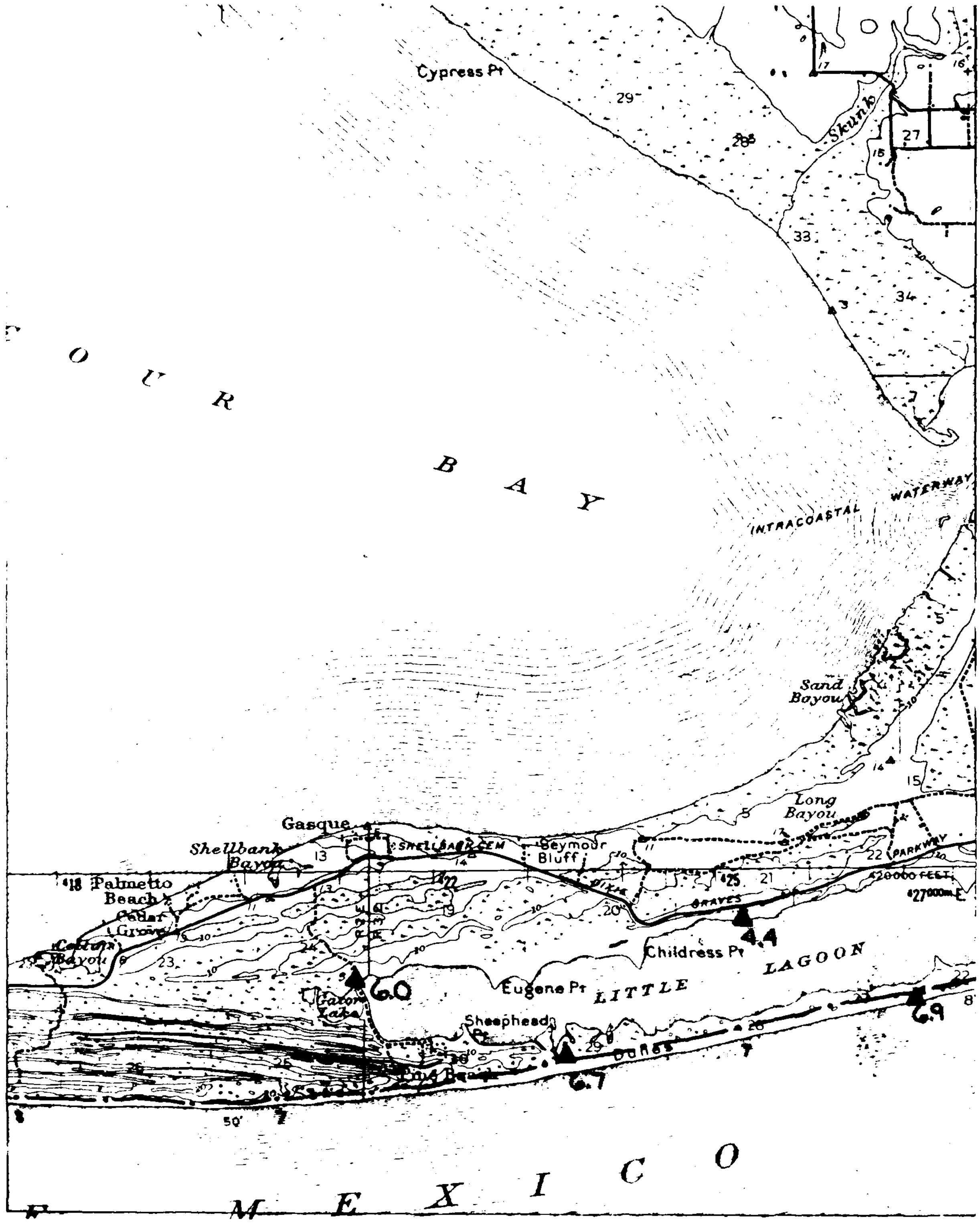



Figure A26. Segment 22, 1/62,500 scale, 10-ft contour interval

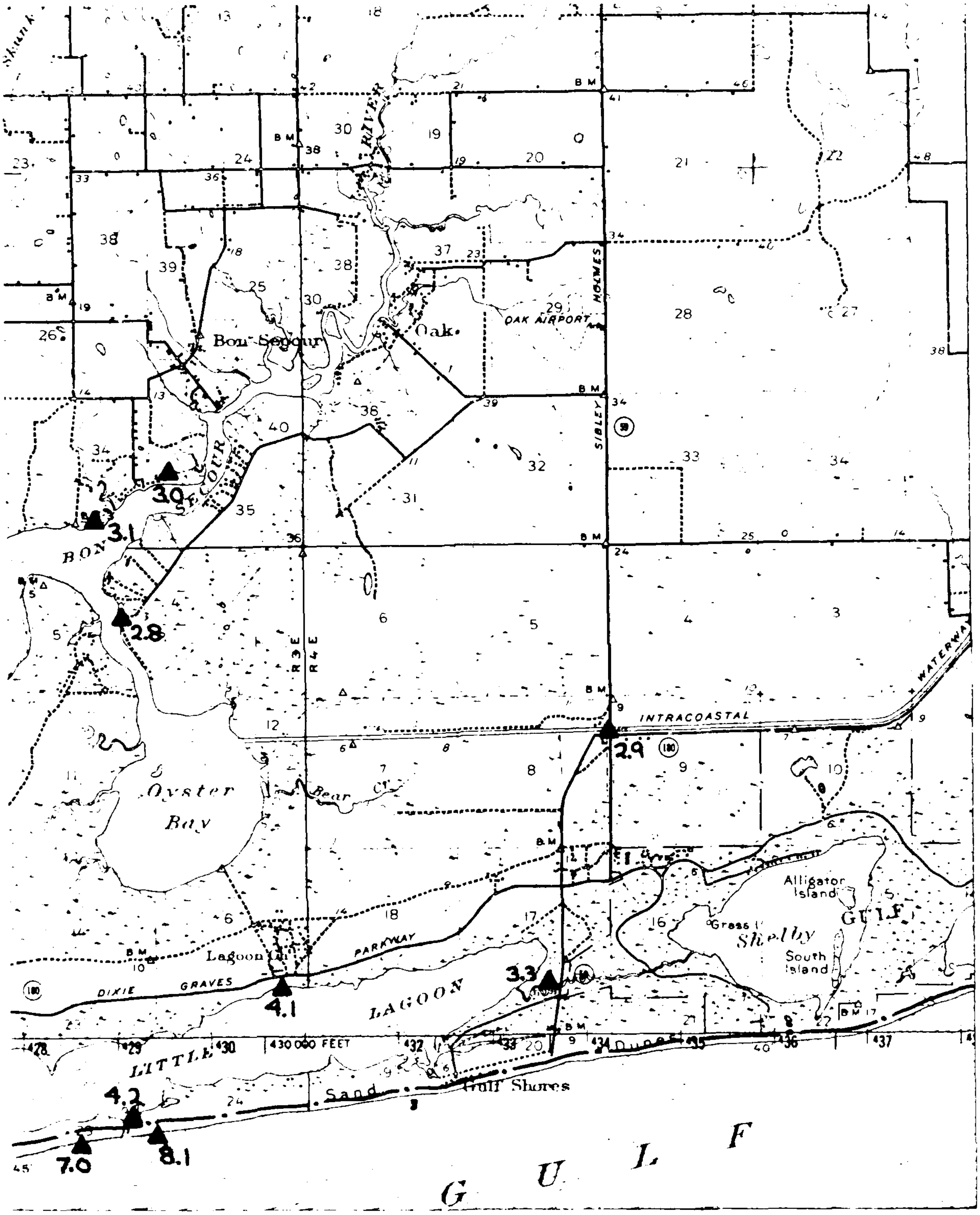



Figure A27. Segment 23, 1/62,500 scale, 10-ft contour interval

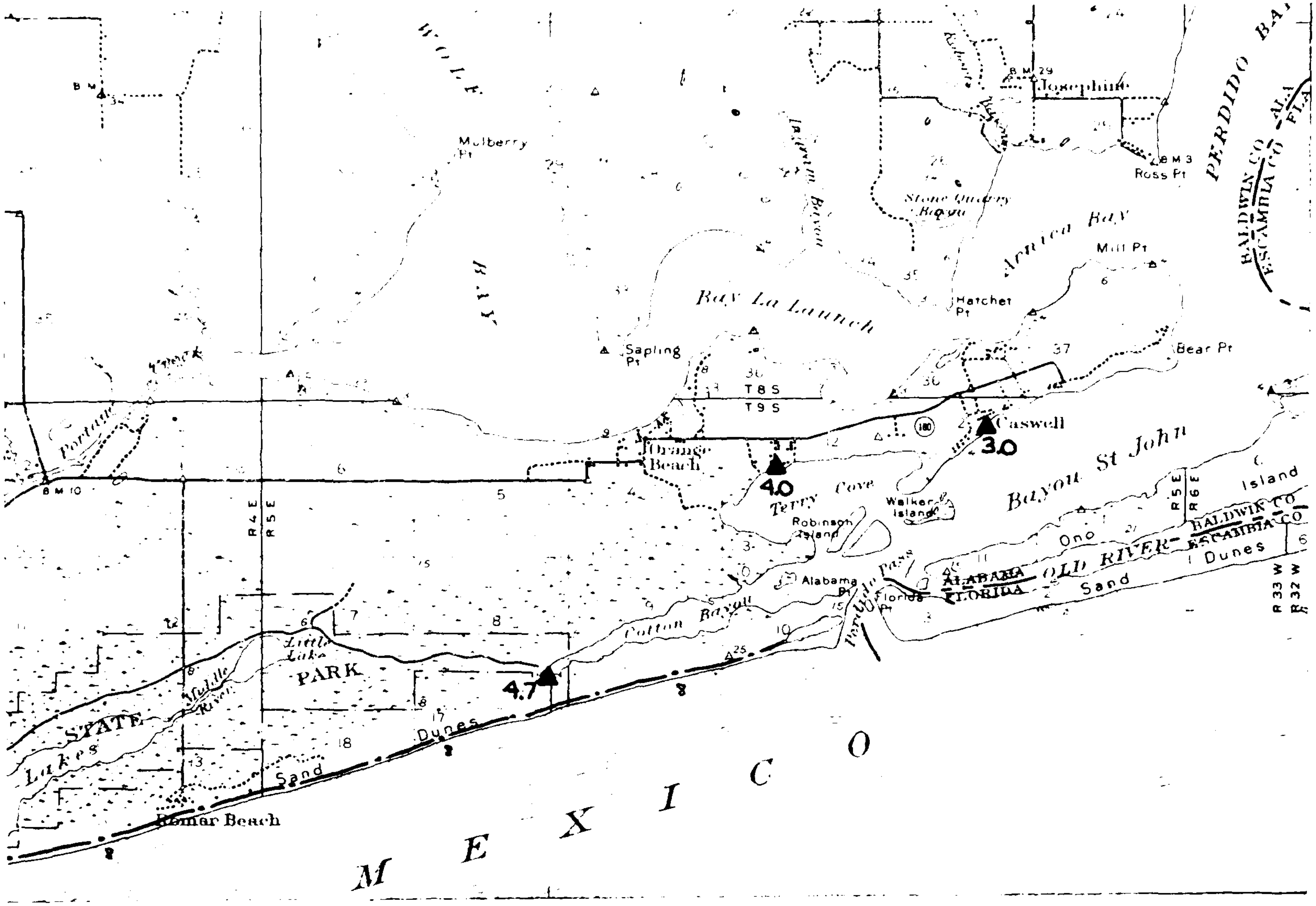



Figure A28. Segment 24, 1/62,500 scale, 10-ft contour interval

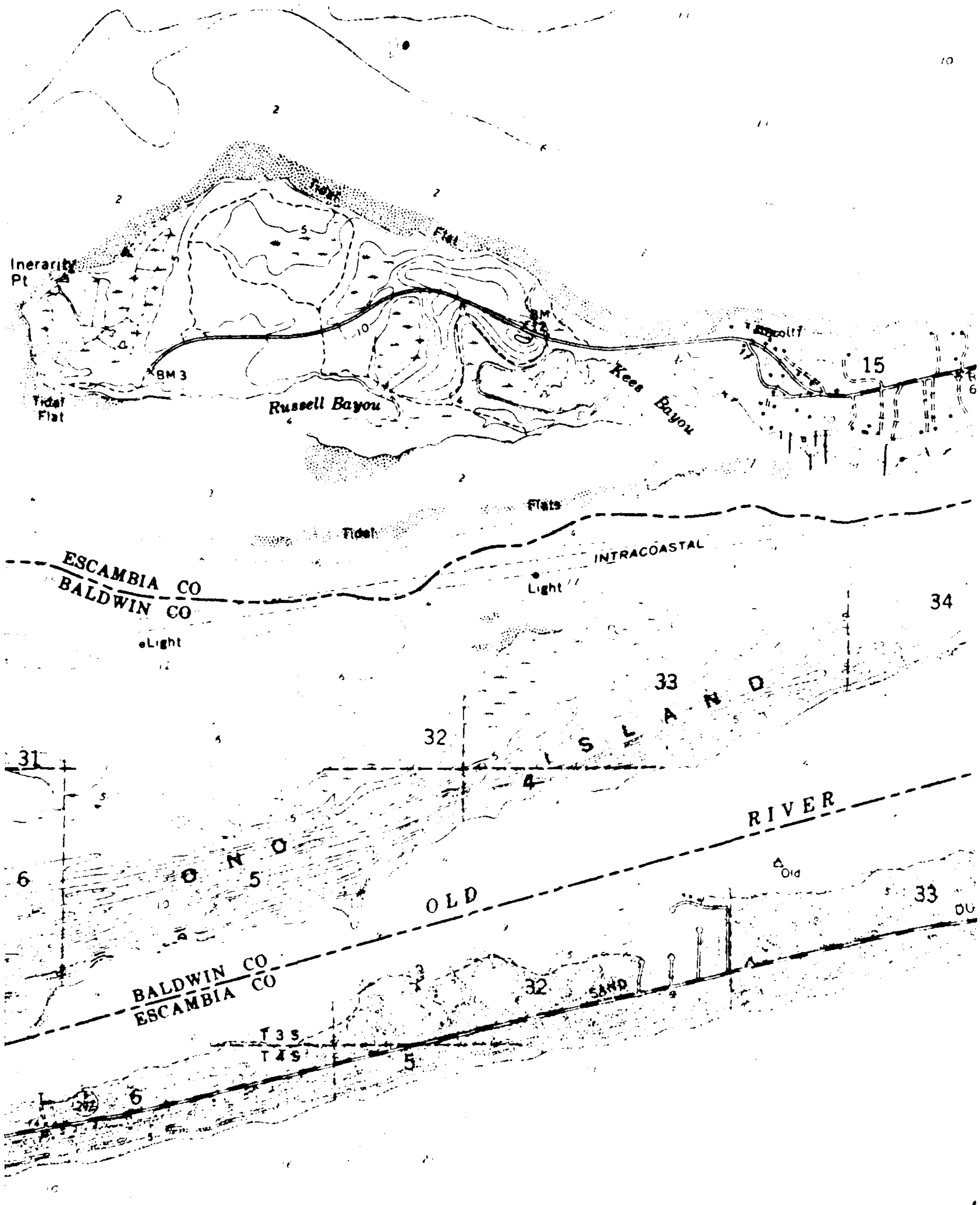



Figure A29. Segment 25, 1/24,000 scale, 5-ft contour interval

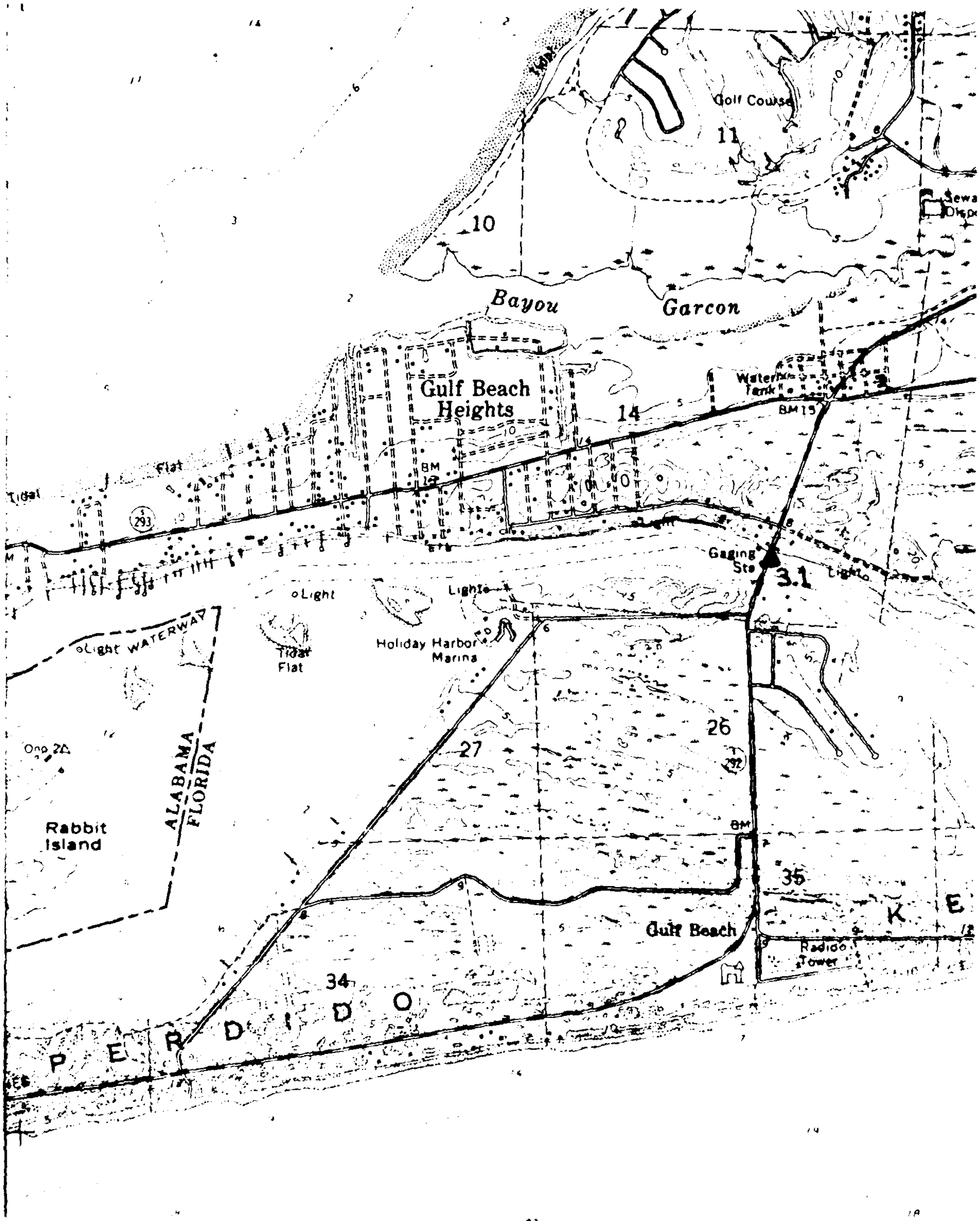



Figure A30. Segment 26, 1/24,000 scale, 5-ft contour interval

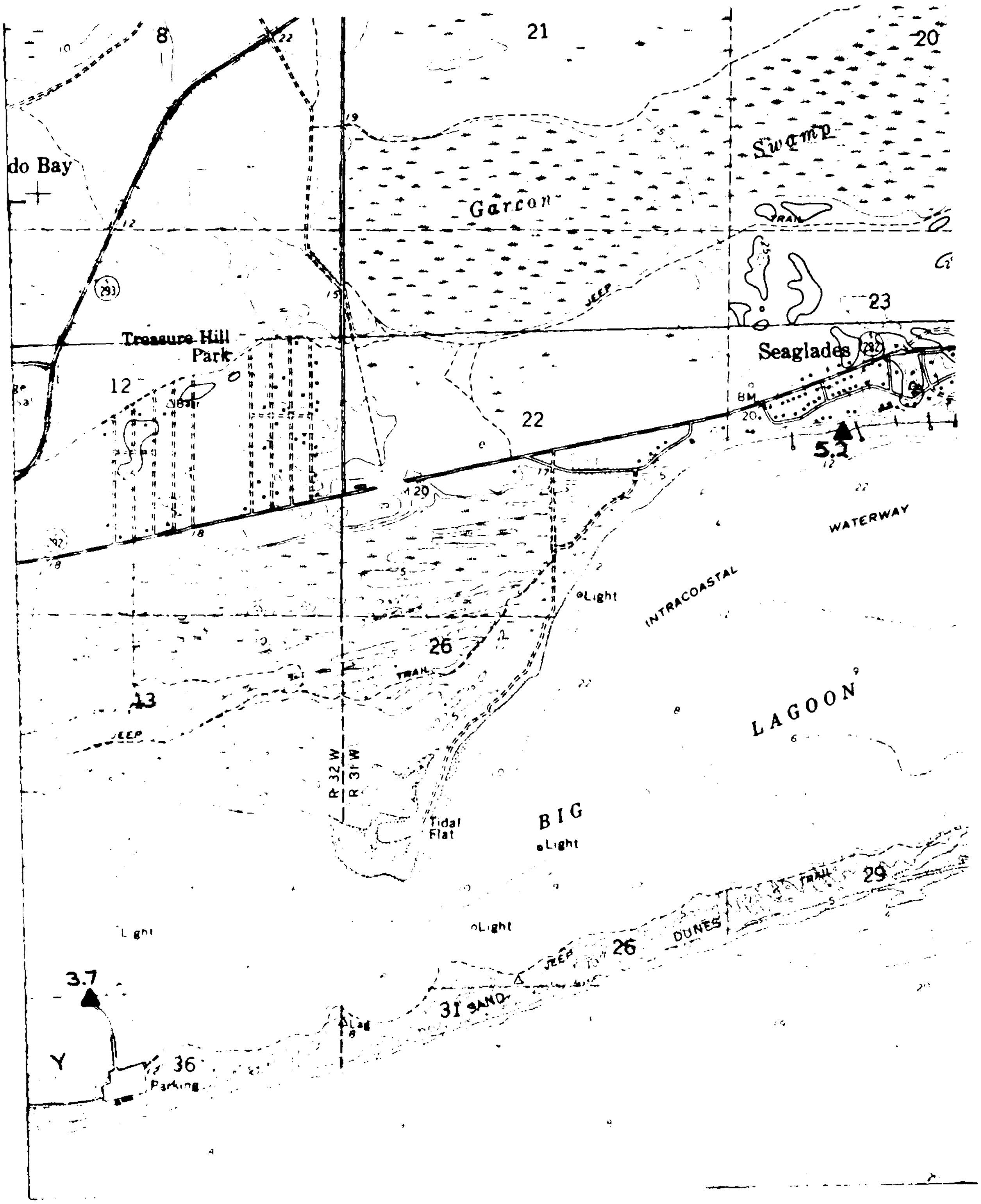



Figure A31. Segment 27, 1/24,000 scale, 5-ft contour interval

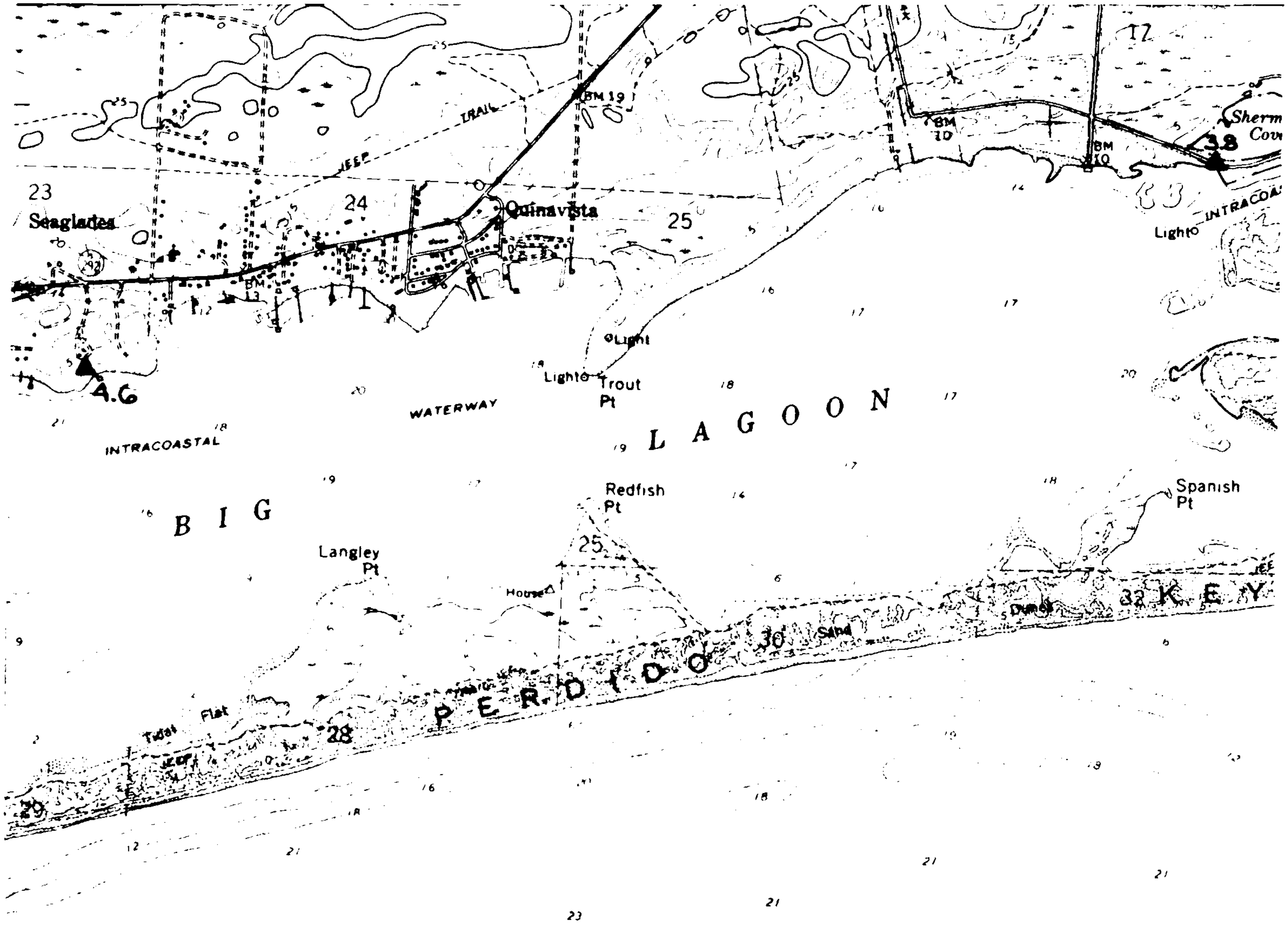



Figure A32. Segment 28, 1/24,000 scale, 5-ft contour interval

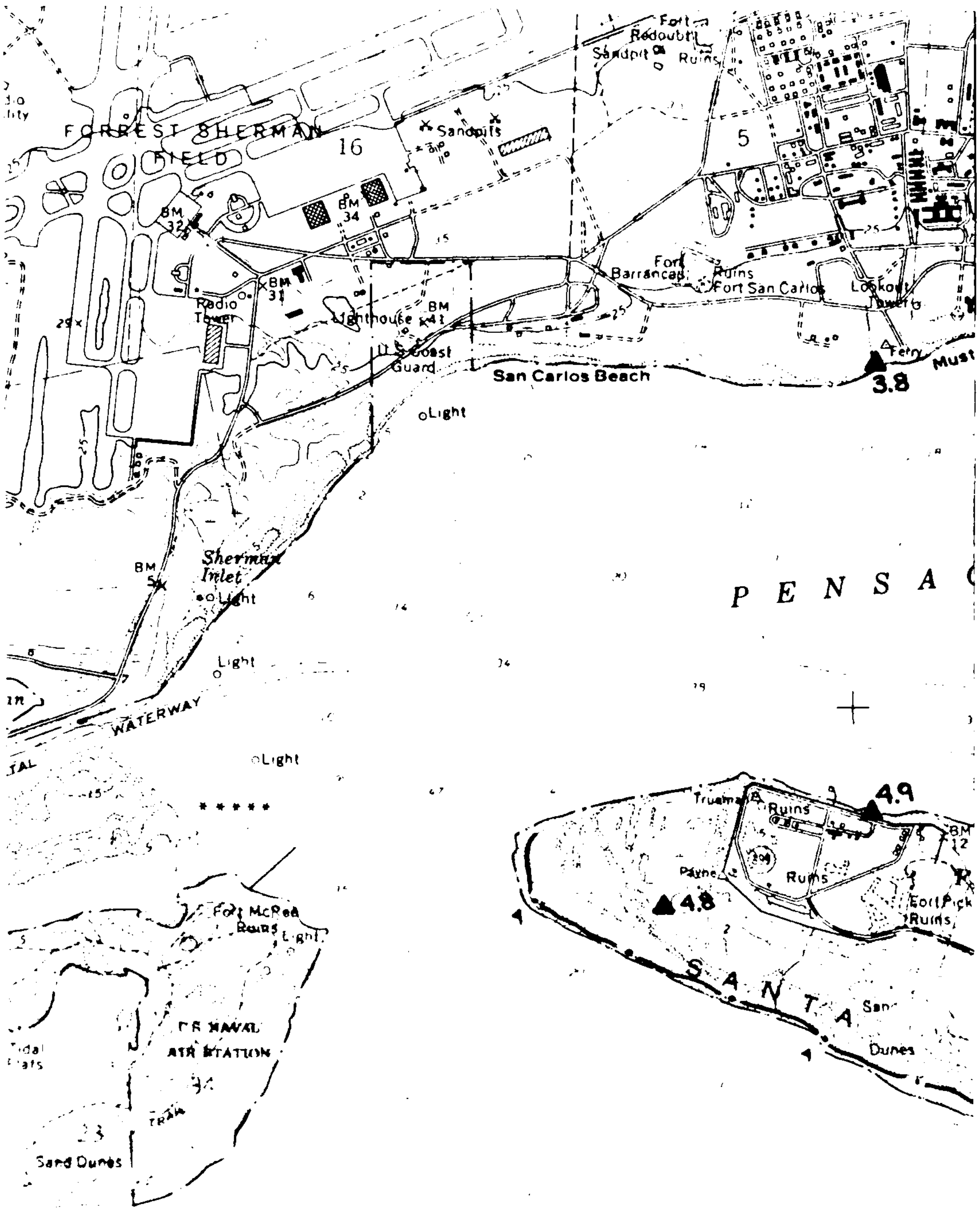



Figure A33. Segment 29, 1/24,000 scale, 5-ft contour interval


Figure A34. Segment 30, 1/24,000 scale, 5-ft contour interval

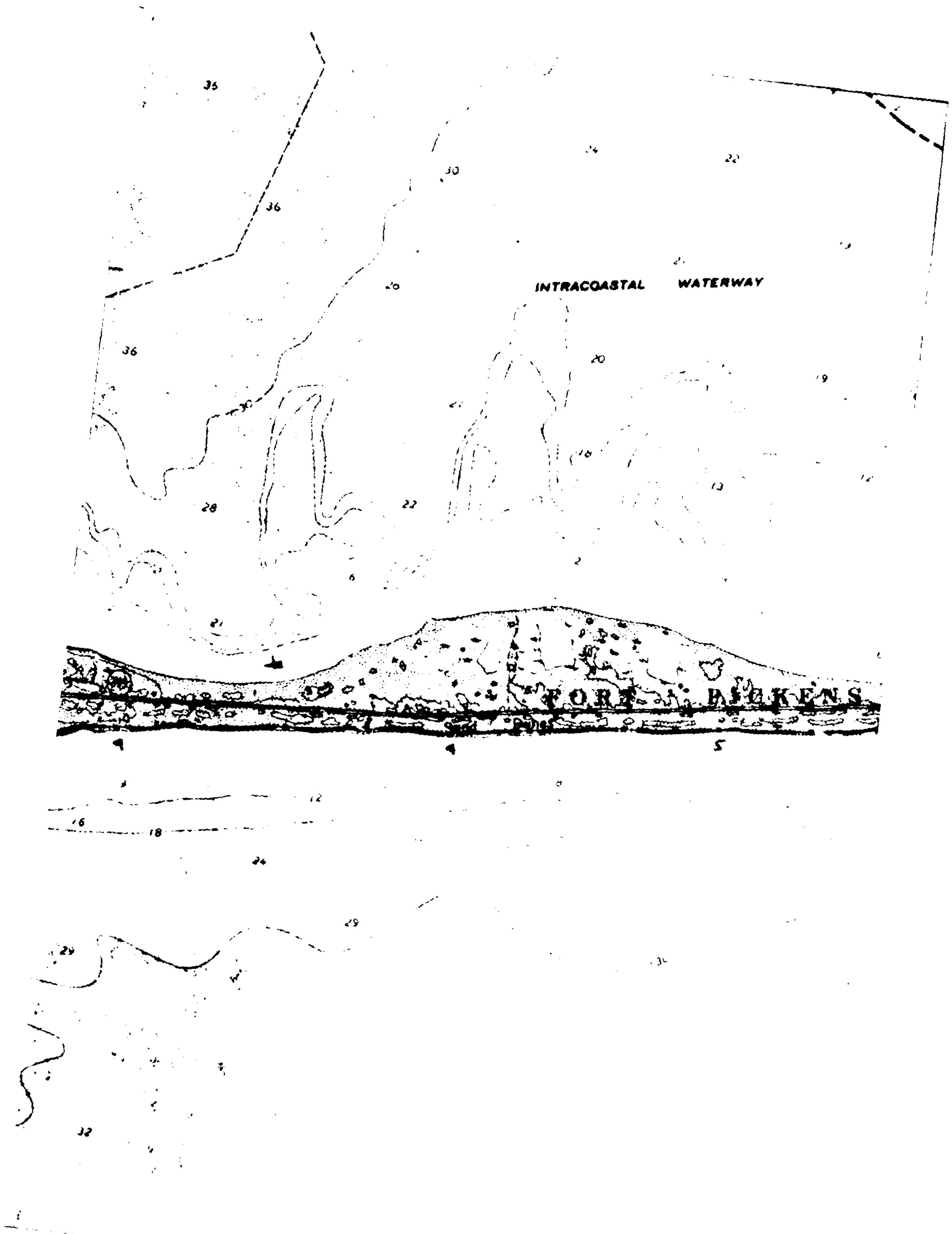



Figure A35. Segment 31, 1/24,000 scale, 5-ft contour interval

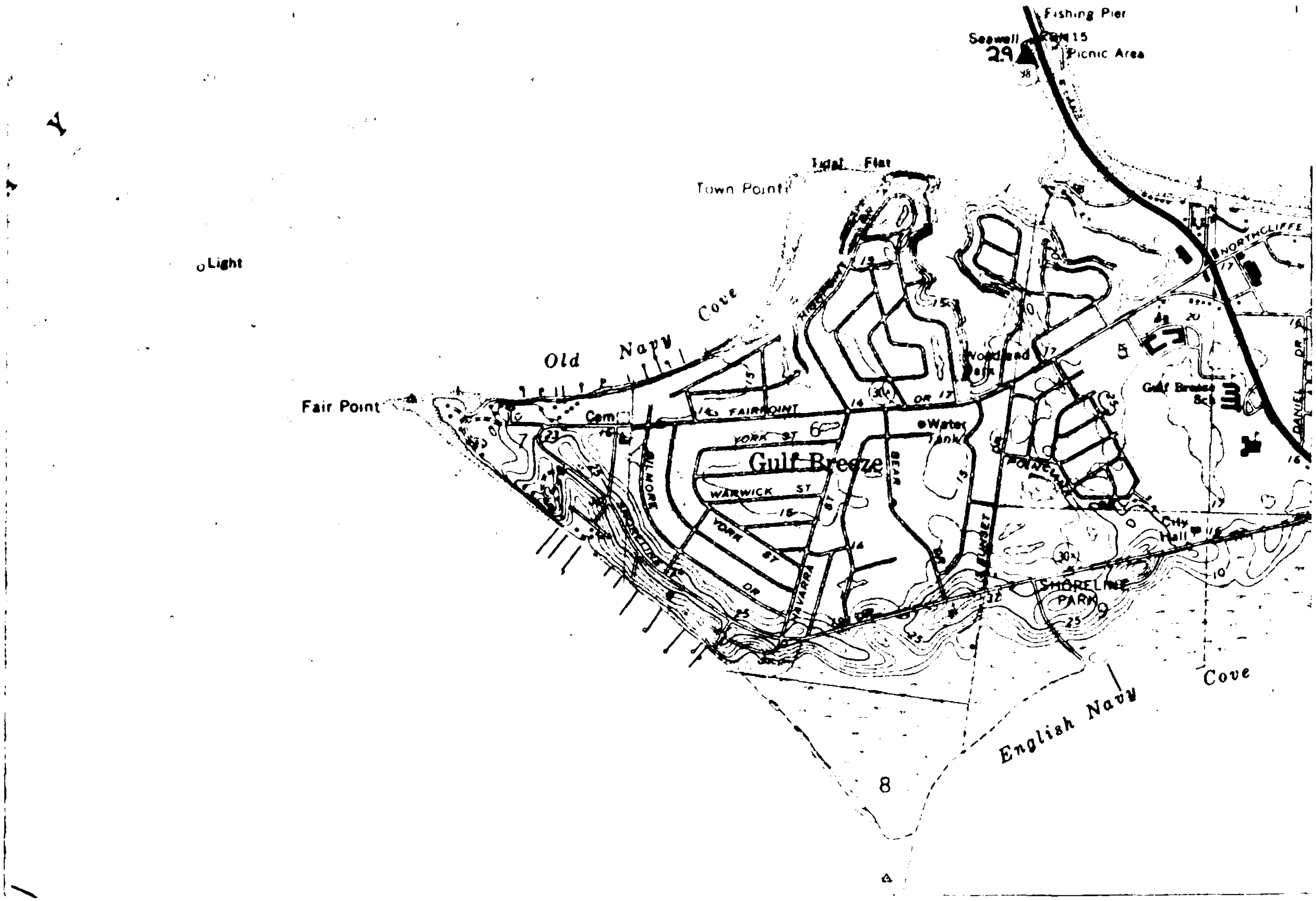



Figure A36. Segment 32, 1/24,000 scale, 5-ft contour interval

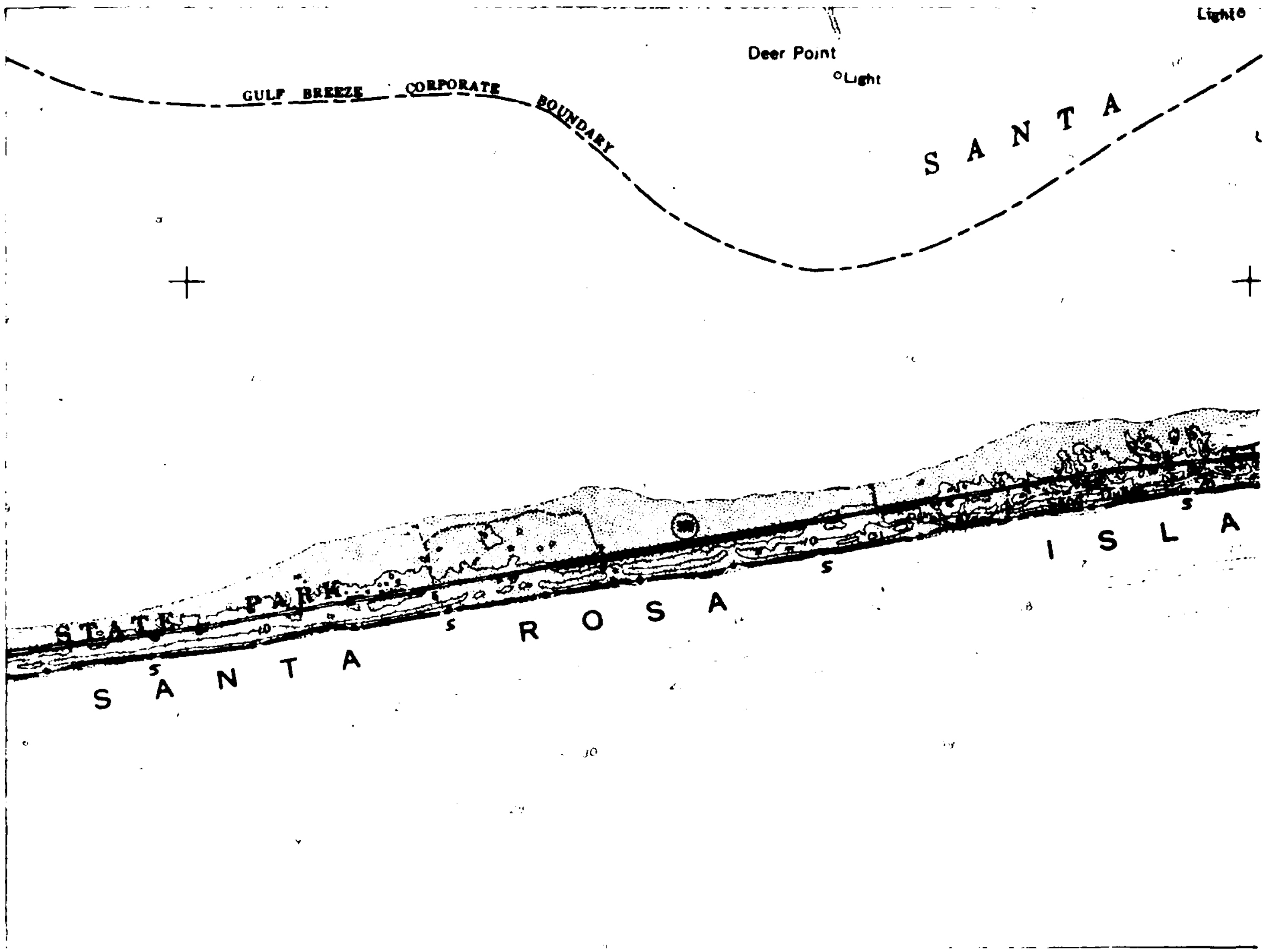



Figure A37. Segment 33, 1/24,000 scale, 5-ft contour interval

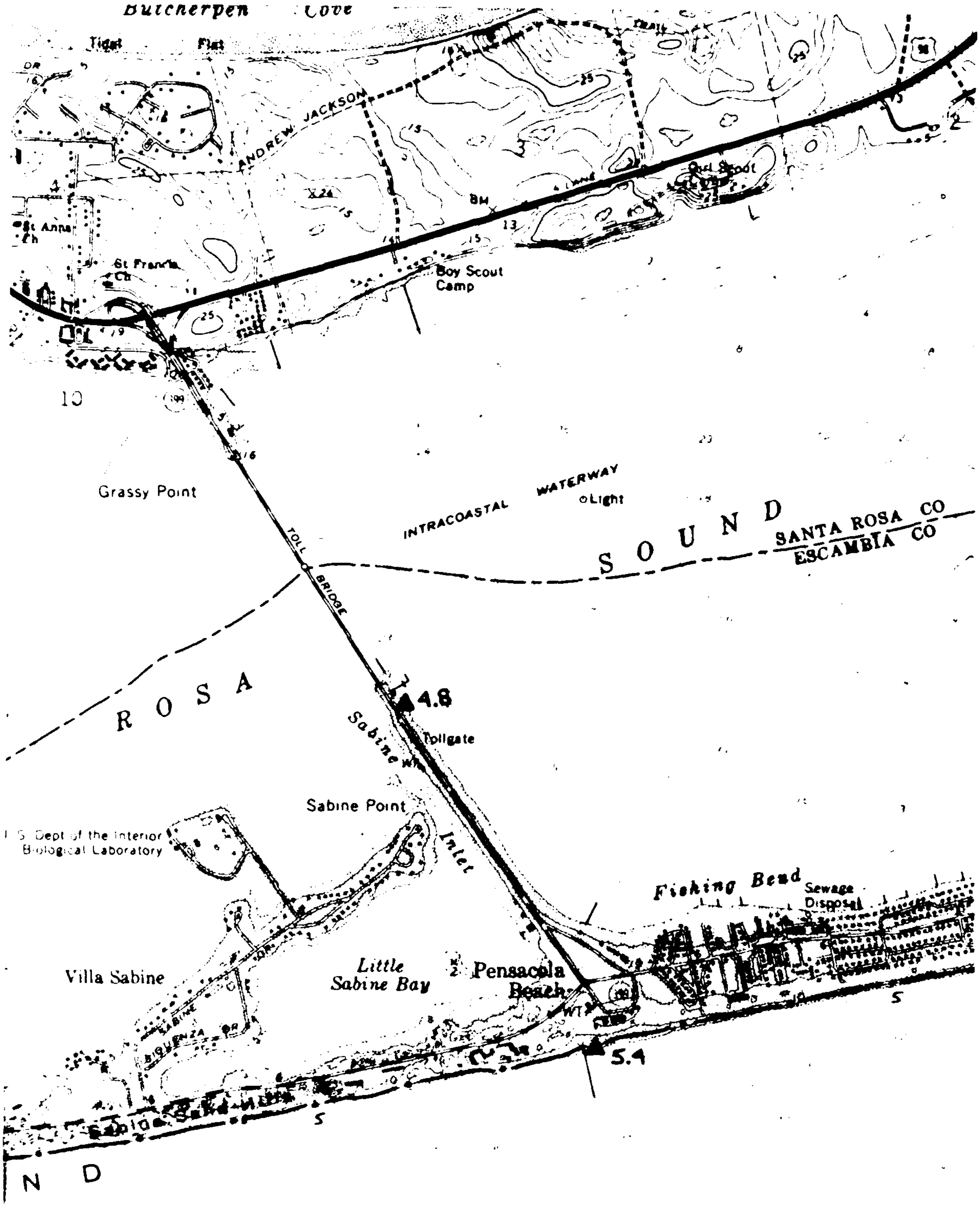



Figure A38. Segment 34, 1/24,000 scale, 5-ft contour interval

END

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